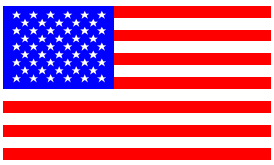

UPPER GREAT LAKES PLAN OF STUDY

for

REVIEW
of the

REGULATION OF OUTFLOWS

from

LAKE SUPERIOR

Prepared for the International Joint Commission
by the
Upper Great Lakes
Plan of Study Team

January 2002

EXECUTIVE SUMMARY

In August 2001, the International Joint Commission (IJC) assembled a binational study team to develop a Plan of Study (POS) to review the operation of structures regulating the outflows from Lake Superior. The study would include a review of the Commission's Orders of Approval and the regulation plan itself. It would also identify the needs of the various beneficial uses affected by water levels and propose possible improvements to Lake Superior outflow regulation. Potential climate changes that could affect water levels and flows of the Great Lakes system would also be considered in the study. This document describes the tasks that would need to be conducted, schedules, and costs.

In its directive to the team, the IJC requested that the POS team develop a plan of study using a number of relevant reports and resources and emphasizing public involvement. In developing this document, several team members participated in the Commission's public meetings that were held on the upper Great Lakes, including Georgian Bay, in June and July 2001. POS team members reviewed correspondence that the Commission received from citizens, interest groups, government agencies, and elected officials. The team consulted experts on ecosystems and the environment; recreational boating; coastal processes; commercial navigation; hydropower; industrial, municipal, and domestic water intakes; public information and education; and hydraulic and hydrologic modeling. The team also consulted with the experts who are currently conducting the Lake Ontario - St. Lawrence River Study.

Following completion of an initial draft POS in early October 2001, the team invited a group of experts in Canada and the United States to conduct a peer review of the initial draft. In late October 2001, the POS team sent the draft POS to nearly 400 members of the public and other interested parties, inviting comments on the document. The team also posted the draft POS on the team's web page at http://huron.lre.usace.army.mil/ijc/uglpos/. Finally, the team held public meetings between October 31 and November 15 at cities on Lakes Superior, Michigan, Huron, Georgian Bay, and Lake Erie, to obtain comments on the draft plan of study. This final POS has been prepared taking into consideration all the comments received.

Study Objectives

Since the criteria for regulating the outflows of Lake Superior were last revised in 1979, the upper Great Lakes basin has experienced several episodes of extremely high and low water supplies. These include the record high water levels in 1985 and 1986, the subsequent rapid drops in the levels in 1987-1988, and the sustained below-average levels from 1999-2001 throughout the Great Lakes – St. Lawrence River system. Concerns have been expressed about the ability of the current regulation plan to cope with these situations as well as with changes in future water supplies due to climate change and variability.

The upper Great Lakes basin's socioeconomic conditions continue to evolve. In addition, our needs and preferences may have changed considerably from those of 22 years ago

(when the regulation criteria were last amended). Today, there is a broad recognition of the importance of the Great Lakes ecosystem. There is an increased awareness that the ability of wetlands to sustain fish and wildlife habitat is very dependent on water level fluctuations. The recreational boating industry and the important tourism associated with it have increased over the last several decades. With the low water levels that began in the late 1990s, the sensitivity of the recreational boating and tourism industries to extreme water level fluctuations is becoming more apparent.

Likewise, the needs of the traditional uses and interest groups – shore property, hydropower and navigation, are evolving. Although their needs are generally well understood, information gathering and evaluation would be necessary to identify better water level and flow criteria for these groups.

This POS is designed with the following objectives, consistent with IJC's directive to the POS team:

- Review the effects and limitations of current outflow regulation procedures
- Evaluate options identified to improve the operating rules and criteria governing the system
- Review past and potential hydrologic and hydraulic changes (including potential climate change and climate variability)
- Assess the ability of the existing Orders and any feasible alternatives to meet the needs of current and emerging beneficial uses and recommend improvements to the Orders if necessary.

Study Scope

In its August 13, 2001 directive to the POS team, the IJC defined the scope of the study that the POS should address. For the study, it is assumed that there would be no changes to the 1909 Boundary Waters Treaty and other bilateral agreements between Canada and the United States. However, potential changes to the IJC Orders, criteria, conditions, and Lake Superior regulation plan would be investigated. Potential changes would be identified and evaluated to determine how they would affect the various resources and interests in the basin, and at the same time ensure they are consistent with the principles and objectives of the Treaties and agreements.

The IJC further directed that the team would not develop any physical structural changes to the system for evaluation. The study would evaluate how the regulation plan or proposed alternative plans function under climate variability and climate change scenarios. Future changes in the basin, including demographics, land use, and water needs, would be considered in developing and evaluating regulation plan scenarios. The impacts of existing major diversions and of past and current dredging of connecting channels would also be summarized, but no investigations into compensation would be undertaken by the study team itself unless such construction plans were in place at the

time of the study.

Although the regulation plan currently is based on a monthly time step, daily flow and water level fluctuations in the St. Marys River affect navigation and likely other beneficial uses in the river. These daily variations would also be evaluated to identify any potential improvements to the regulation of flows that would alleviate adverse impacts on the various beneficial uses.

Phased Approach

The proposed study has been designed to obtain the optimal amount of benefit versus cost. The study would be conducted in two phases. Phase 1 would include studies of the capabilities and limitations of Lake Superior outflow regulation considering the current climate regime and potential climate change. Phase 1 would also define the impact of various regulation changes on coastal resources and other interest groups, and identify potential improvements to the criteria and regulation operations. It would identify the effects of past and current dredging on the outlets of the Great Lakes, and evaluate a pre-regulation scenario for comparison to the current regulation plan. The work in Phase 1 would rely heavily on existing data and ongoing studies, with some new focused data collection to support site-specific studies or pilot studies.

Phase 1 would be designed to meet the overall study objectives. Phase 1 would provide an assessment of the impacts (both negative and positive) of Lake Superior outflow regulation so that the Commission would be in a position to make any needed changes to the regulation plans or Orders. If the needs and impacts of regulation cannot be clearly defined with the available data and analyses in Phase 1, and there appears to be potential benefit from changing regulation, then Phase 2 would be required. Phase 2 would consist of a more detailed evaluation, including data collection, modeling, and analysis to fully characterize and quantify the impacts of regulation changes. The Phase 1 report would provide details on the scope and costs of the additional needs for Phase 2 so the Commission could alert the governments of its finding in accordance with its responsibilities under the Boundary Waters Treaty.

It is expected that the Phase 1 effort would be completed in about three years, with an interim report submitted within 30 months of study initiation. The Study Board would also submit semi-annual progress reports to the IJC. The interim report is timed to allow advance review and discussion of the need for Phase 2, both by the IJC and by the public. A series of public meetings would be scheduled following release of the interim report to discuss the findings and need or lack of need for Phase 2 with the public. Phase 2 could last up to an additional 3 years.

Evaluations

Specific studies would be necessary to define the impacts of water level and flow changes on the various resources (also termed beneficial uses or interest groups) of the basin. A technical resource committee would be established and conduct studies for each of the following areas of interest:

- Ecosystem
- Recreational Boating
- Hydropower
- Commercial Navigation
- Municipal, Industrial, and Domestic Water Uses
- Future Land Use/Basin Needs
- Coastal Zone

In addition, a hydrologic and hydraulic committee would be established to develop appropriate modeling tools and to conduct modeling of various alternative regulation plans. The hydrologic and hydraulic committee would also include experts in climate variability to define a range of future supply scenarios. The geographic area to be studied extends from Lake Superior through Lake Erie, including Georgian Bay and Lake Michigan.

The studies would focus on defining the current state of the resource (which, as used in this document, is defined as a particular interest or use), identifying impacts due to various Lake Superior outflow regulation alternatives and, where appropriate, identifying optimal water level conditions and associated regulation changes to enhance the resource.

The studies would be conducted with a specific focus on regulation plan changes so that this link is made directly. Prior to initiation of the studies, an evaluation committee, consisting of at least one member from each resource committee and experts in decision science methods or other evaluation techniques, would develop an evaluation procedure to compare alternative regulation scenarios. This evaluation methodology must be in place before the individual studies are initiated so that the studies, including data collection, can be tailored to provide the necessary output that is compatible with the evaluation methodology.

Many groups and members of the public who provided input on the POS conveyed a fear that all beneficial uses would not be given equal consideration in the study, that the team would have preconceived notions on the importance of one beneficial use over another. The POS team is strong in its belief that there should be no biases entering into the study itself. The POS team has no such bias and attempted to convey that objectivity in this document. Each technical resource committee will be given an opportunity to define optimal operating conditions for its own beneficial use area and these will be considered collectively. Of course, all users of the system must recognize that in any system that has so many competing uses, benefits to one use often cause adverse impacts on another use.

The study team would develop a means of evaluating various impacts, both monetary and non-monetary, in seeking an equitable recommendation.

Public Involvement

Public consultation is critical to identifying and evaluating the effects of regulation of Lake Superior outflows and any potential improvements recommended to operating criteria and regulation plans. This is a challenging task because of the large geographic nature of the study, encompassing the upper Great Lakes watershed from Lake Superior through Lake Erie.

The team recognizes that a successful review of upper Great Lakes regulation is dependent in large part on the public's understanding of the role of regulation versus natural variability. The POS Team is cautious about creating undue expectations in the public on how much "control" can be exerted over the levels and flows in the upper lakes and connecting channels and any potential improvements that could be made by changes in the operating rules. At the same time, the Public Involvement must be a two-way interaction, with the public fully engaged in all aspects of the study, from developing the goals and objectives to evaluating alternative operating scenarios.

To achieve these objectives, it is recommended that the major interest groups, users, and public be involved directly in the study by the formation of an Interest Advisory Group, described in Section 2.2.1. In addition to providing advice, the IAG members would gain first-hand experience in understanding the limits of regulation and the tough balancing decisions that must be made when dealing with competing uses of water resources.

Another means of ensuring effective communication would be the use of the Internet. The current Upper Great Lakes Plan of Study web page would evolve into a study web page, updating readers on the study progress. Tools would be developed for online "what-if" scenarios so the public can see first hand the effect of various potential regulation changes on levels and flows in the upper Great Lakes and connecting channels, and the limited ability man has to control levels and flows.

Public meetings, newsletters, email notices, teleconferences, and conference presentations would also be used to inform the public about progress of the study and allow the public an opportunity to provide comments and suggestions. The public involvement program would also include recommendations for continual public interaction once the study is complete. This may include improving access to levels and flow data via the Internet, 24-hour phone access, or other means.

Project Management

It is proposed that the overall management of the multi-year study described in this POS

be assigned to a Study Board created for that purpose by the Commission. The Board should assign two study managers, one from Canada and one from the U.S., to manage day-to-day operations of the study. The Study Board would then establish specific binational technical resource committees or work groups that would be responsible for conducting the individual studies, using the available expertise of the two nations, and allocating resources accordingly. Potential agencies and groups that have the necessary expertise for these individual studies are listed in Annex 1.

In addition to the individual technical resource committees that would be conducting the studies, there must be an evaluation team selected at the study initiation. The evaluation team would be responsible for developing criteria for evaluating impacts and responses within technical resource areas and working with the individual resource committees to ensure that the committee's work would provide the information necessary for the evaluation. The Plan of Study Team strongly suggests that one member from each resource committee participate in the evaluation team to ensure continual communication and coordination between conduct of the studies and the required result needed for evaluation.

The Study Board would review periodic reports from each committee and ensure that the overall Study is on track and consistent with objectives and goals of the study. At the completion of Phase 1, the evaluation committee, with input from individual resource committees, would make a recommendation to the Study Board regarding Phase 2. Phase 2 could range from no additional work necessary to more extensive data collection and detailed analytical analysis to support regulation change recommendations. The overall structure of the study management and committees would remain in place for the duration of Phase 2.

Cost Summary

The proposed study has been designed to obtain the optimal amount of benefit versus cost. The study would be conducted in two phases. Phase 1 would require 3 years to complete and is estimated to cost a total of $9.5 million in U.S. dollars**,** which is equivalent to $14.25 million in Canadian dollars (assuming a currency exchange rate of 1.50). This represents the total cost of the Phase 1 study; it is assumed that the cost would be split roughly equally between the two Governments. The study would be conducted, and these funds allocated, to the Study Board, managers, and a series of binational technical resource committees. The teams would be comprised of subject matter specialists serving in their personal and professional capacities from various federal, state, and provincial agencies and academia. Private consultants and stakeholders impacted by Lake Superior outflow regulation could be asked to provide technical expertise to the committees. Overall coordination of all committees would be handled by the binational Study Board.

Phase 2 costs have been estimated to range from $7 to $10 million in U.S. dollars ($10 to

$15 million Canadian equivalent). Phase 2 is presented as a wide range because the exact nature of the required work in Phase 2 would be unknown until the end of Phase 1.

Acknowledgments

This document could not have been developed without the assistance of dozens of individuals who provided critical technical review and assistance in formulating the various approaches. We greatly appreciate their valuable assistance. These individuals are listed in Annex 2.

Respectfully submitted by the Study Team,

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Upper Great Lakes Plan of Study for Review of the Regulation of Outflows from Lake Superior

1. INTRODUCTION

In August 2001, the International Joint Commission (IJC) informed the governments of the United States and Canada of its plan to establish a binational team to develop a Plan of Study (POS) to review the regulation of outflows from Lake Superior. The team would be asked to prepare a detailed POS to review the current operation of structures controlling outflows from Lake Superior and evaluate any options to improve operating rules and criteria. Through such a review, the team would make a determination as to whether or not changes to the Commission's Orders of Approval and the regulation plan that govern the operation of Lake Superior regulation are warranted. This POS, prepared by the team, outlines the basic framework of the Upper Great Lakes Study.

1.1 Background

1.1.1 IJC Directive and Appointment of Plan of Study Team

On August 13, 2001, the International Joint Commission (IJC) established the Upper Great Lakes POS team to prepare a POS designed to review the operation of the structures controlling the outflows from Lake Superior. The team members are listed in Annex 2. As outlined in the directive, the purpose of the study is to:

(i) Review the operation of the structures controlling the outflows from Lake Superior in the light of the impacts of those operations on water levels, flows, and consequently affected interests in the upper Great Lakes system, from Lake Superior downstream through Lake Erie, including the environment.

(ii) Assess whether changes to the Orders or regulation plan are warranted to meet contemporary and emerging needs, interests, and preferences for managing the system in a sustainable manner, including under climate change scenarios.

(iii) Evaluate any options identified to improve the operating rules and criteria governing Lake Superior outflow regulation.

In its directive to the team (Annex 3), the IJC also listed a number of studies or activities that would be required as a minimum. This document describes the required studies, costs, and schedule.

Regulation of the outflows of Lake Superior affects many users in the upper Great Lakes

system. The degree of effect varies, depending on many factors. The primary factors include user proximity to the control works, user needs and preferences, and geographic settings. Improvements to Lake Superior outflow regulation can be identified only after a thorough understanding of the needs and preferences of all the interests in the system, knowledge of prevailing and potential climatic conditions and water supplies, and capabilities of current flow control structures is developed. Considering the complexity and the size of the upper Great Lakes basin, the study must be conducted in a well-focused manner to arrive at the best conclusion and recommendation. In this regard, the POS team recommends that a phased study be conducted. More details are discussed later in this document.

To conduct the study, we propose that technical working groups or resource committees be established to address the key issues. The names of the agencies, academia, citizen coalitions, First Nations, and Native Americans who we believe could make a significant contribution to the study are listed in Annex 1. The IJC should also consider individuals whose expertise would make valuable contributions. A study board would provide guidance and directions to the working groups, make decisions on major study assumptions and evaluation methods, and would direct public involvement programs. We also propose that a two-member binational team of managers assist the Board in planning, budgeting, and public relations activities.

1.1.2 Great Lakes Hydrology

The Great Lakes - St. Lawrence River system is a system of natural reservoirs. The lakes and surrounding land draining into them cover about 774,000 square kilometers (about 300,000 square miles) downstream as far as Cornwall-Massena. Lake Superior flows into Lake Huron through the St. Marys River. Lakes Michigan and Huron are connected by the broad and deep Straits of Mackinac and are considered one lake hydraulically, with lake levels rising and falling together. The lakes are commonly referred to as Lakes Michigan-Huron. Lake Huron includes a very large bay, Georgian Bay, which has unique coastal features.

From Lake Huron, water flows through the St. Clair River, Lake St. Clair, and the Detroit River to Lake Erie. Lake Erie flows into Lake Ontario via the Niagara River. Lake Ontario levels cannot affect the upstream Great Lakes due to the almost 100-meter (300-foot) drop in elevation between Lake Erie and Lake Ontario, most of it located at Niagara Falls and cascades in the Niagara River. Lake Ontario, the lowest lake in the chain, flows into the Atlantic Ocean via the St. Lawrence River. This study encompasses an area from Lake Superior through Lake Erie. The upper Great Lakes basin is shown in Figure 1.

The Great Lakes were formed about 14,000 years ago after the last Ice Age when the glaciers retreated. The basin continues to rebound from the weight that the glaciers exerted on it many years ago. This rebound, referred to as “crustal movement” or isostatic rebound, has resulted in the northeastern part of the basin rising relatively faster than the southwest part. For example, the landmass around Duluth, Minnesota, at the western end of Lake Superior, is estimated to be declining relative to Point Iroquois (at

the eastern end and near the lake's outlet) at a rate of about 25 cm (10 inches) per century. Thunder Bay is estimated to be rising about 2.4 cm (1 inch) per century relative to Lake Superior's outlet. Relative to the outlet of Lake Michigan, Holland, Michigan is currently declining about 8 cm (3.1 inches) per century whereas Collingwood, Ontario has been rising about 17 cm (6.5 inches) per century.

The water levels of the Great Lakes change in response to many factors. Overlake precipitation, surface water runoff, and groundwater flows provide water to the system, while evaporation and outflows decrease water quantities in the lakes.

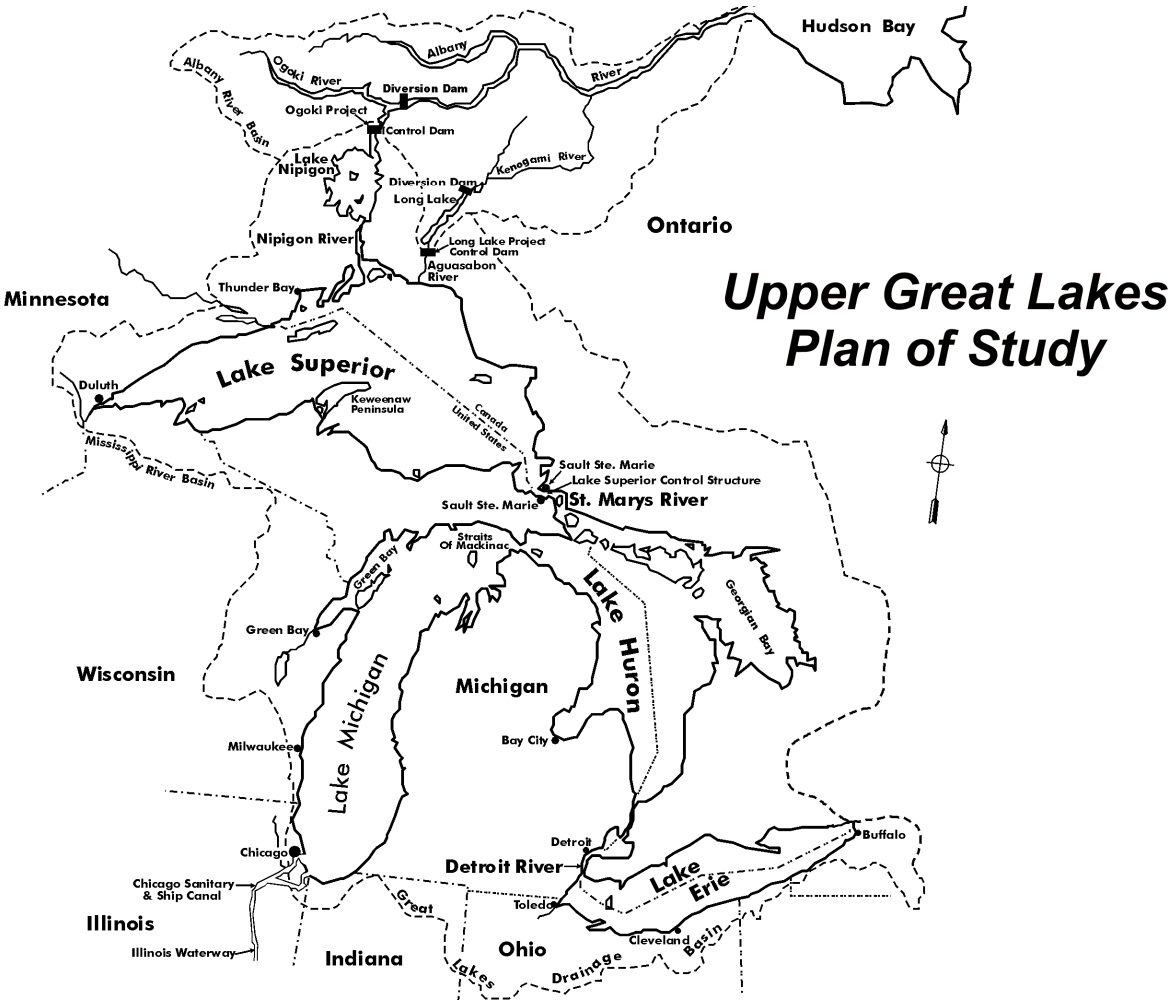

Figure 1: Upper Great Lakes Basin

Persistently high or low water supplies over several years are the main factors responsible for extreme high or low lake levels. Other natural factors that have lesser impacts are flow restrictions due to ice or submerged aquatic vegetation in the outlet rivers. Several

human activities also affect levels and flows, including dredging of channels, water diversions, consumptive uses, and outflow regulation. Consumptive uses are water taken out and not returned to the lakes, such as water incorporated into manufactured products and exported out of the region.

Water levels on the Great Lakes experience three types of fluctuations: long-term, seasonal, and short-term. Long-term fluctuations occur over periods of consecutive years as the result of climate variations affecting the region. Over the coordinated period of record used by U.S. and Canada to reference long-term water levels, record low water levels occurred during sustained drought periods in the 1930s and 1960s. Conversely, record highs occurred during sustained wet periods in the early 1950s, in 1973, and in 1985-86. Water level trends can also reverse quickly, as demonstrated in the drop from very high to very low in a matter of about two years from 1986 to 1988 and again from 1997 to 1998. The unpredictability of the magnitude and timing of natural water supplies to the lakes poses the biggest challenge in Lake Superior regulation.

Some insight into long-term fluctuations over a much longer time period have been offered by recent research into the post-glacial geologic past water levels (Baedke and Thompson, 2000). This research, conducted on Lakes Michigan-Huron, used physical shore features to hindcast water levels several thousand years. The work suggests that Lakes Michigan-Huron experienced long-term fluctuations over periods of about 150-160 years, with lesser long-term fluctuations occurring over periods of 30-33 years. These researchers are currently developing a similar post-glacial water level estimate for Lake Superior.

There is a growing concern about climate change and the effects it may have on the water levels of the Great Lakes. Current research points to an increase in regional temperatures, and possibly increased frequencies of severe weather events. Results from some global modeling studies show a decrease in water supplies to the lakes, which would result in lower water levels and decreased outflows.

Seasonal fluctuations take place during the course of each year. Water levels rise in the spring extending into summer in response to runoff from snowmelt. The levels decline during the fall due to reduced runoff and increased evaporation from the lake. The timing of the seasonal rise and fall varies across the lakes, depending on the position of each lake in the basin and regional hydrologic conditions.

Short-term fluctuations (seiches) are the result of sustained strong winds or atmospheric pressure changes. These do not change the water volume of a lake but do cause large localized water level fluctuations. Strong southwest winds and pressure differences have resulted in the level on Lake Erie at the eastern end near Buffalo, New York being as much as 3.7 meters (12 feet) higher than the western end near Toledo, Ohio. The magnitudes of short-term water level changes due to storm surges are not as severe on the other Great Lakes.

1.1.3 IJC Orders of Approval and Supplementary Orders

In 1914, the IJC issued Orders of Approval permitting Algoma Steel Corporation in Canada and the Michigan Northern Power Company in the United States to divert some St. Marys River water for hydropower generation. The 1914 Orders specified a list of conditions to be met in the construction and operation of the hydropower facilities. This led to the regulation of the outflows of Lake Superior and thus, the creation of the International Lake Superior Board of Control.

The 1914 regulation criteria explicitly recognized three major interests – riparians (coastal zone interests) on Lake Superior, hydropower, and commercial navigation. The criteria supplemented the simple order of precedence listing among the various interests already laid out in Article VIII of the Boundary Waters Treaty of 1909, namely (1) uses for domestic and sanitary purposes, (2) uses for navigation, including the service of canals for the purpose of navigation, and (3) uses for hydropower and irrigation purposes.

The IJC issued Supplementary Orders over the years to meet the changing conditions and requirements in the upper Great Lakes system. A 1978 Supplementary Order permitted the redevelopment of the Canadian hydropower facilities at Sault Ste. Marie, Ontario. In 1979, the IJC amended its 1914 Orders following an extensive study by its International Great Lakes Levels Board and a series of public meetings and consultation with governments. While the previous Orders required that only the levels of Lake Superior be considered in determining Lake Superior outflows, the 1979 amendment, which continues to govern today, requires that the levels of Lakes Michigan-Huron also be taken into account in determining outflows. The objective of this systemic regulation is to provide benefits throughout the upper Great Lakes system.

The 1979 Supplementary Order formally expanded the recognition of riparians to include those on Lakes Michigan-Huron and further downstream. Environment was taken into consideration in 1985 when the IJC authorized, under separate Supplementary Orders, construction of the fishery remedial works in the St. Marys Rapids area, and subsequently issued minimum flow requirements for the remedial works to protect the sport fishery in the rapids section of the St. Marys River.

1.1.4 Current Regulation Criteria and Regulation Plan

The Orders of Approval call for a plan of regulation to determine the outflow from Lake Superior, consistent with the conditions and criteria stated in the Orders of Approval and Supplementary Orders. Since 1916, seven different plans have been used to determine Lake Superior outflows.

The early generation of regulation plans considered only the level of Lake Superior in determining the Lake Superior outflow, because they were designed to comply with the 1914 Order. The last of this type of plan was known as the 1955 Modified Rule of 1949. During the Levels Board study (1964-73), an experimental plan was developed that used the concept of balancing of Lake Superior and Lakes Michigan-Huron levels. That plan,

known as Plan SO-901, was used as a guide for Lake Superior outflow regulation during the mid-1970s.

In May 1977, the IJC requested the International Lake Superior Board of Control to prepare a revised regulation plan to provide benefits to interests throughout the Great Lakes system without undue detriment to Lake Superior interests. In September of that year, the Board submitted a report on the development and evaluation of Plan 1977, which was a refinement of Plan SO-901. Plan 1977 was officially adopted in October 1979. Further improvements led to the adoption of Plan 1977-A, which took effect in June 1990.

The current Lake Superior regulation plan, Plan 1977-A, is designed to meet the conditions and criteria set forth in the Orders of Approval, as amended, while operating within certain restrictions of the existing structures and the river system. Several key criteria contained in the IJC's 1979 Supplementary Order are listed, in part, below:

> *Criterion a: The level of Lake Superior shall be maintained within its recorded range of stage when tested with supplies of the past as adjusted. The regulated monthly mean level of Lake Superior shall not exceed elevation 183.86 m, IGLD (1985), or fall below elevation 182.76 m under these conditions.*
>
> *Criterion b: To guard against unduly high stages of water in the lower St. Marys River, the excess discharge at any time over and above that which would have occurred at a like stage of Lake Superior prior to 1887, shall be restricted so that the elevation of the water surface immediately below the locks shall not be greater than 177.94 m.*
>
> *Criterion c: To guard against unduly low levels in Lake Superior, the outflow from Lake Superior shall be reduced whenever, in the opinion of the (Lake Superior) Board, such reductions are necessary in order to prevent unduly low stages of water in Lake Superior, and shall fix the amounts of such reductions; provided, that whenever the monthly mean level of the Lake is less than 183.4 m, the total discharge permitted shall be no greater than that which it would have been at the prevailing stage and under the discharge conditions which obtained prior to 1887.*

Like its predecessors, Plan 1977 and Plan SO-901, Plan 1977-A uses a technique that attempts to balance the levels of Lakes Superior and Michigan-Huron about their mean levels, giving consideration to their natural ranges. A 16-gate control structure (also called compensating works) and hydropower plants in the St. Marys River are the structures used to adjust the monthly outflows. A minimum gate setting of one-half gate open, or its equivalent, is required at all times for the main rapids. In addition, Gate 1, at the north end of the structure, provides a constant amount of water flow for the fishery remedial works in accordance with the IJC requirement. Gate openings are adjusted each month to achieve, along with the flows through the other facilities, including the U.S. and Canadian locks, the monthly Lake Superior outflow specified by Plan 1977-A.

When the regulation plan calls for lesser flows, a reduction in the allocation of water for hydropower generation usually occurs. At times of extreme high flows, all gates at the control structure can be opened to discharge water in addition to the maximum flows through the hydropower plants. Minimum allowable outflows designed to maintain a minimum water level in the lower St. Marys River are incorporated into the regulation plan. The plan includes a maximum winter allowable outflows to reduce the risk of flooding due to ice jamming in the lower St. Marys River.

The International Lake Superior Board of Control constantly monitors the hydrologic conditions of the upper Great Lakes basin. Each month, the Board determines Lake Superior's outflow according to Regulation Plan 1977-A. Once the needs of fisheries, domestic/industrial water, and navigation are met, the remaining water is allocated equally between Canada and the United States for hydropower generation. Under certain conditions, the IJC approves deviations from the regulation plan on the advice of the Board. These deviations may include outflow variations to accommodate repairs at hydro facilities or the compensating works, to support flow measurements, sea lamprey trapping, survey or environmental study of the rapids, or to deal with unusual water supply conditions.

Flow measurements to verify the accuracy of flows at the hydropower plants require that the flow at these facilities be maintained steady during the measurements. At the present time, these measurements are conducted on an annual basis and are completed within one or two days. At the compensating works, flow measurements, which take place during the daytime, require adjusting the gates at various gate open settings and thus can result in large but short-term water level and flow changes below the structure. The timing of flow measurements at the compensating works is typically scheduled after consultation with the fishery experts and biologists to minimize the adverse impacts on the rapids. These measurements are typically performed once a year in early August and last 5 to 7 days.

To meet energy demand, one of the two U.S. plants and the Canadian plant conduct peaking operations. Typically, flows greater than the allocation are released during weekday daytime hours to meet peak demands. As a consequence, flows much less than the allocation are released during non-peak times such as during the night and on weekends. Peaking operations only occur when the water allocation is less than capacity of the hydropower plants. These flow variations cause water levels to fluctuate downstream of the plants and in the lower St. Marys River. Navigation interests have expressed concerns that flow variations exacerbate conditions in the river when water levels are low, causing shipping delays and cargo reductions. At the present, the impacts of these flow variations on navigation and other interests in the St. Marys River are not precisely known. This report outlines the tasks that would be needed to provide the information and, if needed, identify guidelines on peaking operations to minimize the adverse impacts on other interests.

1.1.5 Recent Studies

The most recent major international study of Great Lakes water levels was conducted under the 1986 IJC reference, following the record high water levels on the upper Great Lakes. The Levels Reference Study (Levels Reference Study Board, 1993) was conducted in two phases, and examined whether flow control structures at the outlets of Lakes Michigan-Huron and Lake Erie would be beneficial to the users in the system. The study also reviewed more than 62 possible modifications to the existing Lake Superior and Lake Ontario regulation plans and settled upon ten modifications to be subjected to the multi-objective, multi-criteria evaluation process. From these, one two-lake (Lake Superior and Lake Ontario) plan, known as Measure 1.21, was selected as the most promising.

Measure 1.21 would modify the outflow forecasts used in Lake Superior Plan 1977-A, increase the maximum winter outflow limit, modify the balancing relationship for Lakes Superior and Michigan-Huron, and revise the minimum flow limit during periods of low levels on Lake Superior. Computer hydrologic simulations were run using historical water supplies (1900 – 1989) and the results of Measure 1.21 compared with the present method of regulation. These simulations showed that Measure 1.21 would lower Lake Superior's long-term mean level by 3 cm (1.2 inches), increase its maximum level by 8 cm (3.2 inches), and lower its minimum level by 5 cm (2 inches). Although Measure 1.21 would have no impact on the long-term mean level of Lakes Michigan-Huron, it would lower the maximum monthly level by 5 cm (2 inches) and increase the minimum monthly level by 8 cm (3.2 inches). The Study Board also conducted some economic and environmental impact studies of Measure 1.21. The Study Board concluded that Measure 1.21 could be implemented at no additional capital cost.

The 1993 final report from the Levels Reference Study Board to the IJC contained a number of recommendations pertaining to upper Great Lakes water levels (Levels Reference Study Board, 1993). These included that:

- The governments give no further consideration to five-lake (all the Great Lakes) or three lake (Lakes Superior, Erie, and Ontario) regulation;
- Lake Superior outflow regulation be modified to achieve water levels and flows similar to those described in Measure 1.21;
- The Orders of Approval for the regulation of Lake Superior be reviewed to determine if the current criteria are consistent with the current uses and needs of the users and interests of the system.
- The International Lake Superior Board of Control be authorized to use its discretion in regulating the outflow from Lake Superior subject to conditions similar to those that authorize discretionary action by the International St. Lawrence River Board of Control.

The IJC reviewed the report submitted to it by the Study Board, and submitted its own recommendations to the U.S. and Canadian Governments (IJC, 1993). In the IJC's report, the first recommendation was passed on to the Governments; this Plan of Study responds to the next two; and the IJC has decided not to act on the fourth recommendation at this

time.

A study that was initiated in response to the findings and recommendations of the Levels Reference Study is the Lake Michigan Potential Damages Study (USACE, 2000). This effort has been underway since 1996 and is being conducted by the U.S. Army Corps of Engineers, Detroit District. The study is developing methods and tools to assist in assessing economic damages due to low water, flooding, and erosion. Many of the tools, methods, and results would be directly applicable to the Upper Great Lakes Study.

1.2 Study Objectives

Since 1979, the upper Great Lakes basin has experienced several episodes of extremely high and low water supplies. These included the record high water levels in 1985 and 1986, the subsequent rapid drops in the levels in 1987-1988, and the current below average levels throughout the Great Lakes – St. Lawrence River system. There have been concerns expressed about the ability of the current regulation plan to cope with these situations and future water supplies due to climate change.

The upper Great Lakes basin's socioeconomic conditions continue to evolve. In addition, our needs and preferences may have changed considerably from those of 22 years ago (when the regulation criteria were last amended). There is a broad recognition of the importance of the Great Lakes ecosystem. There is an increased awareness that the ability of wetlands to sustain fish and wildlife habitat is very dependent on water level fluctuations. The recreational boating industry and the important tourism associated with it have increased over the last several decades. With the low water levels that began in the late 1990s, the importance of this industry to tourism throughout the basin has become very apparent.

This POS is designed with the following objectives, consistent with IJC's directive to the POS team:

- Review the effects and limitations of the current outflow regulation procedures.
- Evaluate options identified to improve the operating rules and criteria governing the system.
- Review past and potential hydrologic and hydraulic changes (including potential climate change and climate variability).
- Assess the ability of the existing Orders and any feasible alternatives to meet needs of current and emerging interests and recommend improvements to the Orders if necessary.

1.3 Geographic Scope

Regulation of the outflows of Lake Superior affects water levels on Lake Superior, Lakes

Michigan-Huron and, to a lesser extent, Lake St. Clair and Lake Erie. Because the flows from the regulatory works and hydropower facilities used for regulation purposes are located at Sault Ste. Marie, Ontario and Michigan, the levels and flows of the St. Marys River in the vicinity of these facilities can also be affected. The study would encompass the upper Great Lakes basin from Lake Superior downstream through Lake Erie, including Lake Michigan and the Georgian Bay. The level of detail for specific geographic sites would depend on results of the hydrologic/hydraulic studies as to the potential impacts of regulation changes on water levels at these sites.

1.4 Functional Scope

Legal Arrangements: For the study, it is assumed that there would be no changes to the 1909 Boundary Waters Treaty and other bilateral agreements between Canada and the United States. However, changes to the IJC Orders, criteria, conditions, and Lake Superior regulation plan would be investigated to identify and evaluate how these changes would affect the user groups and resources, and at the same time ensure they are consistent with the principles and objectives of the Treaties and agreements. The POS team recognizes that there are treaties between Governments and the First Nations/Native Americans concerning the use of basin resources; land claims and land ownership are contentious issues. At this time, it is not known whether potential changes to the regulation criteria and regulation plan that would be investigated in this study would impact the First Nations and Native American's rights and use of resources. We recommend that the Study Board, when conducting its study, be aware of these issues.

Climate Variability: Some scenarios developed from global climate models have indicated that projected climate change conditions in the Great Lakes region could cause a significant drop in water supplies for the Great Lakes – St. Lawrence River basin. These changes would make it extremely difficult for the existing Lake Superior regulation plan to meet the Orders' current regulation criteria and conditions. Depending on how the outflows from Lake Superior were regulated with much lower water supplies, climate change could lead to a permanent decline in the upper Great Lakes water levels. This study would investigate climate change and natural climate variability scenarios on the basin. It would include both increased and decreased supply scenarios. The study would be coordinated with the work ongoing on the Lake Ontario - St. Lawrence River Study.

Mitigating/Alternative Measures: The study would only consider existing regulatory works and existing channel configurations, based on previous studies that demonstrate Lakes Michigan-Huron and/or Erie outflow regulation is not advisable and per direction from the IJC. Wherever applicable, other non-structural measures would be identified to alleviate adverse impacts of water level and flow fluctuations.

Groundwater: The team would investigate the relationship between groundwater and lake levels and flows. Groundwater affects nearshore water supply and ecological issues, baseflow discharges to inland streams, and deep regional groundwater flow regimes. The team would investigate the interaction between groundwater and lake levels and flows as

it relates to climate variability and basin supplies.

Future Basin Needs: Information on municipal and industrial water withdrawals/ diversions would be updated and a general assessment made of their impacts or relationships with Great Lakes water levels. The IJC's recent study on protection of the waters of the Great Lakes (IJC, 2000) would be used as a primary source. In addition, a qualitative assessment of how demographic and other future land use changes may affect user needs, water supplies, and regulation impacts would be made. Future land use in the basin would be projected insofar as necessary to project potential future basin water needs and changes in hydrology. Impacts of basin land uses changes, for example urban development and deforestation, is an issue that may affect future basin hydrology, but would be difficult to quantify within the scope of this study. Any available information from other studies on this subject would be used to the maximum extent possible to supplement the analysis in this study.

Ecosystem: Water level fluctuations are critically important to maintaining a diverse ecosystem. Limiting the range of water levels can lead to decreased diversity and overall health of wetlands and, subsequently, habitat for fish and other species. This study would assess the effect of various regulation scenarios on ecosystem. The ecosystem team would also be tasked with developing regulation plan changes that would enhance the ecosystem resources within the upper Great Lakes basin from Lake Superior downstream through Lake Erie.

Great Lakes Major Diversions: The hydrologic impacts of existing major diversions (Long Lac, Ogoki, Chicago and Welland Canal) on Great Lakes water levels and flows have been determined in several recent studies. For the development and evaluation of new Lake Superior regulation plans, it is assumed that there would be no major changes in the physical structures used in these diversions for the near future. It should be noted, however, that changes in the objectives in the management of the Long Lac and Ogoki (Albany River) watershed are being considered and would change the timing of the diverted water into Lake Superior. In addition, some global climate model results have suggested that water supplies to the Great Lakes could be drastically reduced due to climate change. Reduced water supplies to the basin could lead to reductions in the amount of water that can be diverted via the Long Lac and Ogoki diversions. The study would also assess how these diversions might be affected due to climate change.

Dredging: Consistent with the IJC directive, the impacts of past and current dredging in the St. Clair and Detroit River on the Great Lakes water levels would be summarized. Previous evaluations of this effect would be used as a primary information source. This work would be closely coordinated with other ongoing studies in the basin. If these studies indicate a high likelihood that physical changes could be made to the system (e.g., deeper dredging of navigation channels or dredging compensation), the study would assess the impacts of these changes.

Niagara River Regime Changes: An important outcome of this study is a better understanding of the impacts of man-made changes throughout the basin including

changes in the Niagara River that may have affected Lake Erie water levels. These changes and their effects should be defined and documented, but the study would not consider any future physical changes in this area per the IJC Directive.

Hydropower/Navigation Operations: The public has expressed concerns about operational issues at the hydropower facilities on the St. Marys River. The concerns relate to water level and flow fluctuations caused by the hydropower peaking operations. This study would evaluate the beneficial and adverse effects of flow variations at the hydropower plants and on the navigation and other interests in the St. Marys River. It would identify options, including better communications, and propose guidelines governing hydropower operations to enable efficient use of the water for hydropower purposes and at the same time minimize the adverse impacts on other interests. The study of the impacts of flow variations at the hydropower plants should be given priority.

1.5 Approach

The POS Team has taken a comprehensive approach to develop a focused, phased plan for conducting this study. The POS Team conducted consultation with various stakeholder groups as well as the general public in outlining this approach. A broad spectrum of peer reviewers also contributed to developing the overall approach of the POS. The approach reflects the many years of experience of technical experts involved in the issues of concern in the upper Great Lakes.

Over the past quarter century since the last modification to the Orders of Approval for regulation of outflows from Lake Superior, there have been significant changes in the basin. Population along the coastal zone has increased. In some parts of the basin, demand for coastal property has soared. With this has come an increase in structures along the shore and an accompanying increase in economic losses due to flooding and erosion. Water-based recreation, including recreational boating and fishing, has also increased. Recently, climate shifts have increased ambient temperatures in the Great Lakes basin and reduced precipitation, reducing runoff, and resulting in lower lake levels. Whether this has a component due to long-term climate trends remains to be seen.

With increased population and warmer temperatures, greater demands have been placed on the hydropower industry. The hydraulic characteristics in the connecting channels (the St. Marys River and especially the St. Clair – Detroit River system) have also undergone changes and could see further changes related to navigation. Commercial navigation has been challenged in recent years with the dropping lake levels. Load reductions and additional vessel trips have been necessary to compensate for the low lake levels.

With continual development along the shoreline, wetlands and other critical coastal ecosystems have decreased over the past quarter century. There has also been a heightened awareness of the value of coastal wetlands and an improved understanding of the relationship between water level variations and wetland diversity and health.

Technology has changed at probably the quickest pace of any resource addressed here. Advances in data collection, analysis, and evaluation methods have prompted multiple ongoing studies throughout the basin on a variety of important basin resources.

The many changes that the Great Lakes basin has undergone since 1979 illustrate the reason that the IJC has requested this POS. With competing interests, changing conditions, and valuable resources in play, the IJC recognized the need for a review of the regulation of outflows. However, although there is a need for regulation review, and technological advances would allow for very detailed analysis of potential impacts, the POS team was careful not to recommend a massive data collection effort before the specific needs, uses, and benefits could be determined.

The POS team recommends a phased approach. Phase 1 would consist of five parts, which would be directed by the Study Board and Study Managers:

(1) Assemble study teams and committees to prepare detailed plans for studies on individual resource areas.
(2) Assemble an evaluation team to develop evaluation criteria.
(3) Study teams conduct studies, including hydrologic modeling simultaneously with studies on other resources.
(4) Study teams, working with the evaluation team, evaluate the impacts of a limited number of final regulation plan alternatives on individual resources. Develop an evaluation matrix to assess impacts in positive or negative sense on each resource.
(5) Finally, recommend changes to the Orders and/or regulation plan or, alternatively recommend that Phase 2 be initiated.

For the hydrologic modeling, a number of regulation scenarios would be identified. These scenarios would include quantifying effects on flows and levels from Lake Superior through Lake Erie under current conditions (Plan 1977-A with assumptions regarding current major water diversions, ice, and aquatic vegetation effects on flows), pre-regulation, current regulation before dredging of the connecting channels, and under a range of supply variations (which, by definition would include future basin demands and climate variations). Simultaneously, studies on affected resources (defined as the various interests or user groups) would be conducted. These studies would assess current conditions and develop evaluation tools to both identify changes to levels and flows that would enhance the resource and evaluate how potential changes to the regulation plan would affect the resource. The evaluation team would assess any potential improvements to Lake Superior outflow regulation, to determine feasibility and measure its effects on the various interests.

The studies would rely heavily on existing data, other ongoing studies, and expert opinions. Focused information gathering would be necessary for some of the resources, such as site-specific data collection and pilot studies. No large-scale, basin-wide data collection effort would be conducted in Phase 1. However, Phase 1 would be designed to meet the overall study objectives. Phase 1 would assess the impacts of Lake Superior outflow regulation and provide sufficient information that would allow the Commission

to make any needed changes to the regulation plan or Orders.

If the needs and impacts of regulation cannot be clearly defined with the available data and analyses in Phase 1, and there appears to be potential benefit from changing regulation, then Phase 2 would be recommended. In Phase 2, data collection and detailed analysis would be performed on a much wider scope, including sensitive areas within the upper Great Lakes basin for all resources areas that require additional analysis. The Phase 1 report would provide details on the scope and costs of the additional needs and assessments for Phase 2 so the Commission could alert the governments of its finding, in accordance with its responsibilities under the Boundary Waters Treaty.

It is expected that Phase 1 would be completed in about three years, with an interim report submitted within 30 months of study initiation. The Study Board would also submit semi-annual progress reports to the IJC. The interim report is timed to allow advance review and discussion of the need for Phase 2, both by the IJC and by the public. A series of public meetings would be scheduled following release of the interim report to discuss the findings and need or lack of need for Phase 2 with the public.

If Phase 1 concludes that more detailed data collection and analytical evaluations are required, Phase 2 would be initiated and could last up to an additional 3 years

2. STAKEHOLDER INVOLVEMENT

Public involvement and consultation were critical in developing this POS and would likewise be essential in conducting the study itself. Receiving public input on consequences and effects of regulation changes would enhance the team's understanding of these issues. In addition, progress in addressing water level issues is dependent in large part on the public understanding of the causes and consequences of the water level fluctuations. Further, the understanding that most proposed solutions that would benefit one resource likely would have adverse consequences for other resources must be conveyed. In addition to the public, the study would include many key stakeholders throughout the basin to ensure representation of a variety of views and expertise. This section summarized the public consultation that has taken place in developing this POS and also outlines the public involvement program that would be included as part of the study.

2.1 Results of Recent Public Consultation

In May 2001, the IJC informed the governments of its intention to develop a POS to conduct a review of the regulation of outflows from Lake Superior. Concurrently, the IJC informed the public and invited comments on the draft directive setting up the POS team. The IJC received many comments and advice from citizens and elected officials, coalition and interest groups, academia, industries, and government agencies. The IJC documented the many comments and advice it subsequently received (Annex 5).

In addition, the IJC held public meetings in the basin to hear views and concerns, and solicit opinions from the public and citizen groups on the proposed study. Some of the POS team members attended these meetings, which took place as follows:

- June 25, 2001, Sault Ste. Marie, Ontario
- June 26, 2001, Sarnia, Ontario
- June 27, 2001, Port Severn, Ontario
- July 9, 2001, Duluth, Minnesota
- July 10, 2001, Thunder Bay, Ontario

In all, about 70 members of the public attended the five public meetings. In some cases, they represented large interest groups. For example, the Shipping Federation of Canada represented shippers throughout Canada and the Georgian Bay Association represented 4,300 families. There was overwhelming agreement and support for a review of the regulation criteria. In addition, some specific concerns were raised about certain uses. These concerns were all considered by the POS team during preparation of the draft POS.

In early October 2001, the team invited a panel of experts in Canada and the United States to conduct a peer review of the draft POS. Later in the same month, the team finalized

the draft POS and mailed close to 400 copies to the public, interest groups, elected officials, and First Nations / Native Americans, requesting comments on the document. Next, another round of public meetings was held, as follows:

- October 31, 2001, Duluth, Minnesota
- November 1, 2001, Thunder Bay, Ontario
- November 5, 2001, Sault Ste. Marie, Ontario
- November 6, 2001, Muskegon, Michigan
- November 7, 2001, Milwaukee, Wisconsin
- November 13, 2001, Parry Sound, Ontario
- November 14, 2001, St. Clair Shores, Michigan
- November 15, 2001, Cleveland, Ohio

A toll-free call-in number was also made available at the Milwaukee and Parry Sound meetings to accommodate members of the public who could not travel to meeting locations. About 80 members of the public attended this second series of public meetings. The vast majority of participants represented some 20 different non-governmental organizations, several of which have memberships numbering in the thousands. Broad support was expressed for both the study and the proposed approach. Specific comments for additions or improvements to the document were made in all the meetings. The team considered all these comments in finalizing the POS.

In preparing this POS, the team also conducted targeted consultations with interest groups. Interest groups included in these formal and informal consultations included:

- Hydropower
- Commercial Navigation
- Residential property owner associations
- Recreational boating
- Ecosystem
- First Nations/Native Americans

Some of the groups provided comments on the study objectives relative to their interests. Others simply used the consultation as an opportunity to become informed on the intent and schedule of the study.

The POS team took the views and opinions collected from these consultations into account developing this POS.

2.2 Public Involvement Program

Public involvement is a critical element in reviewing the regulation of outflows and potentially recommending improved criteria and regulation plans. The team recognizes that many resources and interests are keenly concerned about variations in water levels

and flows. Many of these interests have competing recommendations for water level changes. The success of the study would be dependent in part on conveying the complex issues regarding competing uses of the waters to the public and furthering the understanding that most proposed solutions that benefit one resource would have some negative consequences for others.

In addition to obtaining views and opinions from the public, it is equally important that the public and interested parties are informed on the limitations of regulation of Lake Superior outflows and its effects on downstream levels and flows. The public information program must convey the understanding of the relationship of natural vs. anthropogenic effects on water levels and flows.

To achieve this understanding, it is recommended that the major user groups and a select number of the public be involved directly in the study. The POS team recommends that an Interest Advisory Group (IAG) be assembled to ensure that the interests and issues of major affected groups and parties are represented in a formal way during the study. For the general public, a web site should be developed to allow the public to remain up-to-date on issues related to the study. Further, a simplified "model" of the upper Great Lakes basin would be made available via the Internet to allow the public to see the effects and limitations of regulation changes. Finally, a communication structure would be established to inform the public on matters related to water levels and flows. This communication structure would ensure appropriate communication on Lake Superior regulation after the study is complete.

2.2.1 Interest Advisory Group

An IAG would be established to participate in the entire study process. The IAG would have membership on each of the committees, and thereby have significant influence upon the direction of the study. Through the IAG, the public would help shape the goals and objectives of the studies, develop evaluation methodologies, identify possible regulation scenarios, and provide input in other critical components of the study.

The IAG would include members representing each of the interests, with representatives chosen through their affiliation. These would include riparians, commercial navigation, hydropower, recreational boating and tourism, ecosystems, fisheries, municipal and industrial water users, and others as appropriate. The IAG would include representatives from Canada and the U.S. from Lake Superior down through Lake Erie.

Members of the IAG are expected to assist with other public involvement efforts using their own local contacts. For example, a representative of a shoreline property owners group that participates on the IAG would be expected to keep its members up to date on the activities and efforts of the IAG and the study itself. This will help facilitate communication to all interested parties and the general public.

It is critical that the public involvement process begin early and continue throughout the study. The IAG should be established at the study initiation and should meet twice a year, as a minimum.

2.2.2 Upper Great Lakes Study Public Communication

Ongoing public involvement in executing the study would be accomplished through a variety of means, including public meetings, workshops, conference presentations, newsletters, email, and the Internet.

The POS team established a web page during development of the POS to provide information to interested parties regarding the POS development. Once the study is initiated, this web page could evolve into a study web page to provide a means of ongoing public communication. The web page could contain, at a minimum,

- Objectives/Goals of Study
- Plan of Study
- Study Board Members
- Interest Advisory Group Members
- Resource Committee Members
- Descriptions on ongoing studies
- Searchable metadata system, describing distributed data that reside on users' systems
- Individual Committee Reports on methods and results
- A simple interactive module that allows the user to test different regulation options and view resulting levels and flows
- Any graphics or powerpoint presentations developed to help explain study objectives/goals
- An area that allows public to provide feedback and to add their name to a mailing list for notification of public meetings and events

The web page would be the primary communication tool with the public and other interested parties. Another communication tool would be a study newsletter that would be sent to all interested members of the public on a semi-annual basis. The newsletter would serve to update the public on studies underway, any results available, and other current events related to the study. The newsletter would be sent to members of the public, agencies, and groups that participated in the POS consultation as well as names added to the mailing list through the web page. This newsletter would also go to media outlets with news releases highlighting any interesting developments. In addition, conference calls could be used to communicate study progress to interests around the basin.

Public meetings would be planned on an annual basis to communicate with the public in a more formal manner. The meetings could be coordinated to coincide with the International Lake Superior Board of Control's annual meetings or other related events.

In addition to mailouts and internet notices, the team should also use newspapers and radio to publicize public meetings. Conference presentations for regional conferences are another good means of communicating the study goals and early results with the technical community.

2.2.3 Post-Study Public Communication Program

An issue of public involvement that would be addressed during the study is recommendations for ensuring appropriate communication with interested parties following completion of the study. Many interested parties could benefit from easier access to water levels and flow data.

The study team would tackle this issue and develop recommendations to address this need. Recommendations could consist of a 24-hour phone access to levels or flows in connecting channels or be as complex as establishing personalized wireless web access to specific levels and flows of interest, which could be convenient for navigation interests and boaters. Safety issues regarding unusual releases, for example, could also be communicated by these means. The study team would investigate a wide range of communication enhancements and make recommendations on the most feasible options.

2.2.4 Cost and Schedule

The costs for a Public Involvement Program in Phase 1 of the study, including salaries and travel, are estimated as follows:

	Year 1	Year 2	Year 3
Total Cost (U.S. dollars)	$200K	$200K	$200K
or			
Total Cost (Canadian dollars)	$300K	$300K	$300K

The total cost for Public Involvement Program for Phase 1 of the study would be about $600K (U.S. dollars). This is equivalent to about $900K in Canadian dollars.

If Phase 2 is implemented, the costs are estimated to be similar to the effort for Phase 1, that is, $600K (U.S. dollars) or $900K (Canadian dollars).

3. DATA SOURCES AND ACQUISITION PLAN

3.1 Necessity of Appropriate Resource Information

There are several ways to approach a study for a system with as many complexities as the upper Great Lakes basin. The approach recommended by the POS team consists of conducting studies on each affected resource using the data, tools, and results developed in other similar studies on the Great Lakes. The study team and experts consulted during the development of this POS believe that optimal benefit would be achieved using a phased approach as outlined in this POS.

A technical resource committee would be established for each of the major resource or study areas:

- Ecosystem
- Recreational Boating and Tourism
- Hydropower
- Commercial Navigation
- Municipal, Domestic, and Industrial Water Use
- Coastal Zone (shoreline interests)
- Future Basin Changes
- Hydrologic/Hydraulic Evaluations (including climate variability)

Each resource committee would identify and review all available data, assessments, and evaluations on that particular resource. The data would be evaluated for its appropriateness for use in this study. A literature review and survey of technical experts would be conducted to help identify possible data sources, ongoing studies or evaluations, and results from previous work. Appropriate agencies at state/provincial and federal levels and universities should be contacted to identify available assessments and evaluations, particularly related to the relationship between the resources and water level fluctuations. Each committee would be expected to assemble all relevant data, evaluations, and assessments collected and use this information to determine the effects of various operating scenarios (and resulting water level/flow variations) on the resource. If applicable for the resource, the study should also identify the range of flows/levels that would optimize conditions or that would have harmful effects on the resource.

The team has designed Phase 1 of the study so that existing data, including the results of previous research and ongoing efforts by others, with some additional studies would be used to identify the needs and impacts of regulation on the affected resources. However, if, at the conclusion of Phase 1, greater clarity were needed to define the impacts of potential beneficial changes in regulation, then further new data collection and analysis would follow in Phase 2. Each resource study report in Phase 1 would outline the requirements for a Phase 2 study. The Phase 2 study could require more extensive data

collection and analysis to determine the potential impacts on resources or to recommend optimal regulation options for the resource.

3.2 Coordination with Other Studies

Recent work has generated extensive information on the perceived needs of various basin resources in relation to water level fluctuations. However, data in a form required to quantitatively analyze the effects of different outflow regulation criteria and plans on the interests are not yet available. Useful, representative information pertaining to the ecosystems, wetland habitats, and shore property are key examples.

There are many key studies either recently completed or ongoing on the Great Lakes that can provide valuable information for this study. These include:

- Lake Ontario - St. Lawrence River Study
- Lake Michigan Potential Damages Study directed by the U.S. Army Corps of Engineers, Detroit District for prediction of damages due to low water, flooding, and erosion and recreational boating impacts
- Lower Great Lakes Erosion Study (LGLES) directed by the U.S. Army Corps of Engineers, Buffalo District for information gathered on shoreline characteristics of Lake Erie
- Canada/Ontario Great Lakes Shore Damage Survey directed by the Ontario Ministry of Natural Resources in 1975
- District Shoreline Management Plans by the Ontario Ministry of Natural Resources
- Lakewide Management Plans for Lake Superior (Lake Superior Binational Program, 2000) and Lake Erie (U.S. Environmental Protection Agency and Environment Canada, 2000)
- Lake Michigan Lakewide Management Plan (LaMP) by the U.S. Environmental Protection Agency
- Lake Huron Initiative by the Michigan Department of Environmental Quality
- St. Marys River and Lake Huron GIS project by the Michigan Department of Natural Resources and Ministry of Natural Resources
- Great Lakes Navigation Review directed by the U.S. Army Corps of Engineers, Detroit District
- Great Lakes Water Resources Management Decision Support System funded by the Great Lakes Protection Fund for evaluation of the use and management of surface and groundwater resources
- Global Climate Change Project directed by USGS
- Levels Reference Study directed by the IJC for its work on identifying Lake Superior regulation variations
- Protection of the Waters of the Great Lakes: Final Report to the Governments of Canada and the United States, directed by the IJC in 2000
- Feasibility study of increasing maximum allowable vessel draft, by the St. Lawrence Seaway Management Corporation

- Ontario Ministry of Environment, Report of Mobile Air Quality Monitoring on Georgian Bay Shorelines, 2001
- Water Quality Assessment Reports, Township of the Archipelago and Township of Georgian Bay
- Wetlands Study: Impacts of Low Water Levels, Georgian Bay Association Foundation
- State of the Lakes Ecosystem Conference proceedings
- Ontario Government's Great Lakes Heritage Coast Initiative

In addition to using the data, methods, and findings from other ongoing studies, the study team must also review the studies that are seriously considering any physical changes that could affect water levels and flows and incorporate those changes into the "future basin needs" analysis.

It may be useful for the committees to hold discussion scoping sessions when collecting data from others so that the interrelationships among various efforts become more apparent to all participants. Guidelines for data storage and sharing also need to be established. Due to the geographic diversity of the study and study participants, it may be most advantageous for the team to develop a web-based approach to data dissemination.

4. SPECIFIC STUDIES AND EVALUATIONS REQUIRED

4.1 Ecosystem

The ecosystem resource area covers a broad spectrum of valuable individual resources on the upper Great Lakes from Lake Superior through Lake Erie that could potentially be affected by changes in regulation of Lake Superior outflows. Ecosystem is defined for purposes of this document as a community or assemblage of living things, together with their environment. The community of living things that will be addressed under the ecosystem evaluation area will include wildlife, fish, and supporting habitats and food web organisms. Ecosystems of particular interest are coastal habitats including wetlands, where water levels changes on the order of centimeters or decimeters could shift or alter them significantly.

4.1.1 Relationship to Water Level Fluctuations

Variation in water levels over cycles of hours, days, seasons, years, decades, and beyond is a feature of the Great Lakes that sets them apart from other aquatic systems in North America. Existing ecosystems have evolved under conditions of water level variation since Holocene glaciation. Natural variation in annual levels of the Great Lakes is caused by climate-driven precipitation and evaporation patterns in the watershed and over the lakes. Crustal rebound since glaciation (causing some parts of the basin to slowly sink and others to slowly rise) also affects natural variation in lake levels over decades.

In the 20th Century, water levels of Lakes Superior and Ontario were affected by human structures that regulate outflows for purposes of hydroelectric power generation, flood control, and commercial navigation. The effect has been to reduce long-term variation especially in these lakes, but has also influenced lake levels for all of the Great Lakes.

Differences in shoreline topography, geomorphology, and geology among the upper lakes affect the manner in which the physical environment and biological communities respond to water level variations. For example, much of the Lake Superior Canadian shoreline is composed of a rugged bedrock shoreline, with beaches and wetlands occurring within some embayments, near river mouths, and in areas of lower topography. In other areas of the basin, the coastal zones may be comprised of active beaches or bluffs of less consolidated material. In these areas, erosional and depositional processes vary with storm events, water levels, and flows.

Because of the great variability of the upper Great Lakes shorelines, there is a complex array of response mechanisms of both the physical and biological environment to water levels changes. This response would be expected to differ in relation to the vertical range of variability (i.e., depth), the spatial extent of the area affected, and the duration of flooding or exposure (e.g., daily vs. seasonally vs. long-term).

Shallow habitats of the nearshore and coast are disproportionally more influenced by lake levels than are deep waters. Small (centimeter) shifts in lake levels can alter the extent, structure, and functions of coastal habitats, and alter the extent of interaction between coastal and nearshore habitats. Most habitats and fish and wildlife populations occur in nearshore and coastal sites, and these zones are high in biodiversity. Human uses of natural habitats are highest in coastal and nearshore areas. Coastal habitats are maintained in states of arrested succession owing to annual and greater cycles of variation in Great Lakes water levels.

Daily flow variations due to hydropower peaking operations and releases from control structures have the potential for affecting local ecosystems significantly. For example, in the St. Marys River, changes in flows can affect spawning fish, fish substrate, and other aquatic organisms.

Seasonal water-level variation is caused by watershed drainage of snowmelt and precipitation minus evaporation, which influences the growing season processes of habitats and fish and wildlife populations. Aquatic and wetland habitats, such as submerged vegetation, coastal marsh, beaches, mud bottoms and flats, shrub carr, and forested wetlands, form complexes and arrays supported by lake-level variation. Such ecosystem complexes serve many functions that are important to humans, such as reducing erosion; filtering nutrients, contaminants, and sediment; supporting populations of fish, wildlife and other aquatic biota, and commercial products such as wild rice and marsh hay; maintaining native biodiversity; and providing aesthetic and inspiring sites for tourism.

The study would include an assessment of the impacts on the St. Marys River ecosystem, particularly of flow variations by the hydropower plants at Sault Ste. Marie, Ontario and Michigan. Other impacts that should be assessed are water level and flow variations due to flow measurements at Sault Ste. Marie, and meteorological factors. This study would help identify guidelines governing hydropower operations, to be confirmed at the completion of the study.

4.1.2 Information Needs

4.1.2.1 Decision-support systems / models

Fundamental to understanding the relationship between management of Lake Superior outflows and the coastal ecosystems of Lakes Superior, Michigan, Huron, St. Clair, and Erie is development of various mapping and modeling tools. Decision-support tools allow us to synthesize information about relationships and to hindcast and forecast conditions based on alternative regulation scenarios. A spatially explicit (GIS-based) system can incorporate information on both landscape configuration and ecosystem quality and relationships to water levels.

Ideally, in order to predict the responses of ecosystems to water level changes, a decision-support tool with predictive capability would use detailed information on topography /

bathymetry, particularly for shallow-water nearshore and coastal systems. Features of the Great Lakes basin that would be critical to such a decision-support tool include: elevations of river mouths, connecting channels, wetland connections, and other important interface sites, fine-scale bathymetry of at least a few key habitats (nesting beaches, various wetland types, coastal forests, etc.) and compilations of spatial and temporal data on habitat types, fish and wildlife populations, sources of nutrients and contaminants, and indicators of ecosystem integrity. At a minimum, fine-scale bathymetry data on representative habitat types would enhance our ability to predict effects of changes in regulation as opposed to variations due to climate.

A binationally agreed upon classification system and map of bottom types and habitat types would be essential for hindcasting and forecasting. Such a system could be built upon existing information. However, the availability of accurate current data would have to be investigated and resources would be needed to bring together information in a unified tool. Clearly, better information on bathymetry would enhance decision-making. The Phase 1 effort would include analyses on a limited number of representative sensitive sites where existing data are available or can be readily obtained. Detailed data collection would be conducted only if it is deemed necessary as a part of Phase 2.

Establishment of coordinated and complementary monitoring programs would enhance our ability to determine the effectiveness of outflow management on ecosystem quality. National, provincial, and state efforts are underway or being planned for monitoring various features of nearshore and coastal ecosystem condition. For binational assessment and evaluation purposes, a status and trends program that is coordinated and complementary across state and national boundaries would be useful in evaluating the response of ecosystems to both management and natural influences on lake levels.

Such monitoring programs are underway and supported by various agencies in the U.S. and Canada. Examples of ongoing efforts to develop indicators of ecosystem integrity include the State of the Lake Conference (SOLEC), Lake Management Plans (LaMPs), studies supported by the U. S. Environmental Protection Agency (Great Lakes Environmental Indicators Project; Great Lakes Wetland Consortium), U. S. Geological Survey Global Change Program, results of the IJC Levels Reference Study, and individual efforts by provinces and states. This study should fully utilize information generated from these programs. This study does not include funding for monitoring programs but efforts can contribute to compilation, display, and analysis of existing data, in partnership with ongoing and developing monitoring efforts.

Efforts are underway related to the development of a decision support model with predictive capabilities that link hydrologic information with environmental conditions. For example, the Great Lakes Commission is currently developing a decision support system, funded by the Great Lakes Protection Fund, to assist the Great Lakes Governors and Premiers in evaluating proposed water withdrawal requests. The application of such a model for this study would be explored.

4.1.2.2 Resource-specific analyses

Resource-specific analyses are needed to relate the landscape-scale patterns to ecosystem functions and biological populations and communities. Endpoints for analysis include resources such as fisheries, wildlife, wetlands, and other habitats important to ecosystem sustainability. Resource-specific analyses can fill important gaps in decision-support tools to aid us in understanding and predicting responses of ecosystems to changes in Lake Superior outflow regulation vs. natural variation, climate, and other human effects.

Since the nearshore, shallow water environments are the areas most affected by water level fluctuations, it is important to identify these areas in Lake Superior, Michigan, Huron, St. Clair, and Erie. For example, Thunder Bay on Lake Superior, Green Bay on Lake Michigan, Saginaw Bay and the Les Cheneaux Islands on Lake Huron, and the western end of Lake Erie are several regions with significant areas of coastal wetlands. The Georgian Bay and Apostle Islands are examples of regions with islands containing unique coastal habitat. Local experts and agencies could be an important source of information on the location of coastal wetlands.

Another relevant investigation was just completed by the Nature Conservancy. This study was an ecoregionally based planning initiative that identifies critical conservation areas within the U.S. portion of the Great Lakes region. This process, and more in-depth site-specific conservation planning efforts, have yielded data that would be extremely valuable for the study. The study team should coordinate with the Nature Conservancy on the use of these results in the Upper Great Lakes Study to ensure that the full range of biological diversity is considered in any future regulation regimes for the Upper Great Lakes.

The ecosystem resource committee should also investigate the latest methods that have been shown to have applicability for specifying an economic component for ecosystem work. Significant research is currently underway in this arena and may have merit for assessing impacts of proposed changes in outflow regulation on various components of the ecosystem. This is not to say that the ecosystem effects should be measured in strictly an economic sense, for there is certainly great intrinsic value in maintaining a diverse, natural ecosystem. The team should carefully consider the tools available to measure ecosystem effects and choose an appropriate method.

WETLANDS: Coastal habitats are known to contract and expand as long-term lake levels rise and fall. Such variation maintains important habitats in arrested succession and leads to local and regional biodiversity and support of populations and communities of native flora and fauna. Long-term variation in water level results in a dynamic balance between woody and herbaceous plant communities and between emergent, floating, and submersed plant communities. However, extended years of very high or very low levels may have an adverse impact on wetland habitat sustainability and species richness.

Another basic question is the effect of variation in lake level (or reduction of variation), especially due to outflow regulation, on shoreline ice effects. Ice is known to alter the

edges of habitats; both during the winter and during spring break-up. Ice can remove soil and vegetation and erode surfaces, and likely serves to set back the succession of plant communities and to open niches. Little is known about the role of long-term lake level variation on shoreline ice effects and habitat structure, although data exist in some quarters to approach an analysis. If lake level variation is reduced, ice effects could be more or less severe on coastal habitats; this may be important to the structure and function of coastal ecosystems. Integrating historical ice cover data into decision-support tools or spatial analyses would advance the understanding of lake level variation relationships to ice effects as well as the relative role of outflow regulation.

Seasonal water level variation also affects ecosystems. Most critical are the potential problems related to aquatic life accessing shallow water habitats. If water levels drop too low in winter, muskrats and other animals that are dependent on under-ice habitat can be left high and dry. If water levels increase too quickly in the spring and then decline at the time that coincides with fish spawning, fish may not be able to gain access to streams or wetlands required for spawning. In some areas, if the water levels rise too slowly in the spring, fish can also be restricted from access to spawning sites.

Submerged aquatic vegetation (SAV) is a required habitat for many species of fish and wildlife. SAV can be an important factor in controlling erosion and in trapping suspended material and nutrients. The health of SAV beds is tightly coupled with water clarity, since the plants depend on adequate light penetration in water for growth and reproduction. Coastal erosion, tributary discharge, eutrophic growth of plankton and periphyton, and suspended solids can all limit or eliminate SAV in aquatic ecosystems. The effects of long-term lake level variations on factors affecting submerged vegetation beds should be studied.

Most critical in this study is to develop predictive capabilities to assess the effects of alternative regulation plans on coastal wetlands from Lake Superior down through Lake Erie.

FISHERIES: Populations of commercial and recreational fish and their supporting food webs, along with other key native fishes, depend upon nearshore and coastal habitats for growth and reproduction. Even some deepwater species, such as lake trout, have been shown to depend on coastal resources for growth. Many lake trout populations spawn in nearshore waters with depths as shallow as one meter (about 3 feet). These fish spawn in response to water temperature, which is moderated by water levels and physical processes of the lake. As water levels drop, temperatures may become less suitable on certain reefs. Some reefs may become too shallow, and normally suitable reefs may become more vulnerable to warmer temperatures. Reefs are also susceptible to more wave energy damage as a result of declining water levels.

Evaluation of outflow regulation should include an improved understanding of the population support (support for growth and reproduction) of coastal habitats for fish species. Such evaluations should recognize landscape-scale coastal habitat mosaics and their relationships to commercial and recreational fisheries and their supporting food

webs. Periods of high lake levels enable fish to penetrate the coastal marshes, enhancing their prey avoidance and feeding and reproductive habitat. Years of low lake level stimulate regeneration of deep-marsh species and their critical structure for food, spawning habitat, and protection for fisheries. Recreational species, such as walleye, northern pike, smelt, and other species are particularly adapted to shallow water habitats that expand in area during high lake level years. However, for some wetlands, particularly on the Georgian Bay, years of low water levels may mean a critical loss of habitat for some species like the Northern Pike and smallmouth bass.

The relationship of lake level variation and groundwater inputs is important because many fish species require cold-water inputs from groundwater into coastal and tributary habitats. There are a number of fisheries monitoring programs in the Great Lakes, from which data could be mined in analyses of long-term lake level influences on fish resources. Seasonal lake level variations are also critical in assessing impacts on habitat.

COLONIAL BIRDS: The Great Lakes coastal zone supports colonial nesting birds on beaches and in rookeries. Such habitats are characterized by, in the former, open beaches, and in the latter, stands of trees protected from human disturbance. Both habitats afford breeding birds both protection from predators and abundant aquatic food items. Both habitats are susceptible to vegetation succession and are maintained in early successional states by long-term variation in lake level. The effect of alternative regulation scenarios on the populations of these bird species in the Great Lakes should be considered. The possibility that species may adapt to changing conditions and/or that other bird species may replace existing species should also be considered. With the decision-support tools previously mentioned, data from ongoing monitoring programs could be mined to examine the relationships between coastal bird populations and lake level variation.

AMPHIBIANS AND REPTILES: Coastal habitats, such as wetlands and beaches, support a diverse array of amphibians and reptiles. Populations of these faunal groups are closely related to habitat condition. Concern has arisen worldwide about declines in populations from multiple causes, including habitat loss. Monitoring programs are being developed around the Great Lakes (for instance, Frog Watch, the North American Amphibian Monitoring Program, and the Marsh Monitoring Program), but as yet do not include a lake-level effect component. Knowledge on the relationships between lake level, habitat structure, anthropogenic stressors, and populations of amphibians and reptiles would be needed to determine whether changes in outflow regulation could have deleterious impacts on populations. However, the study team should understand that current monitoring programs are very new and their reliability not yet proven. This issue should be pursued, but any conclusions resulting from it will need to be carefully evaluated and may have to be qualified, depending on the current state of the science.

RARE PLANT AND ANIMAL SPECIES: The coastal zone of the Great Lakes supports habitats containing rare plant and animal populations, including threatened and endangered species. Such habitats depend upon fine-scale habitat diversity associated with water level variation and unique temperature and substrate conditions. Rare arctic and marine coastal disjunct species seem to depend upon the unique features of portions

of the Great Lakes coastal zone. The relationships with their habitats are as yet poorly understood. Many such species occur in the narrow zone that is affected by long-term variation in lake level. Special attention should be given to understanding their habitat needs and forecasting whether changes in the regulation of Lake Superior's outflows would affect their supporting ecosystems. Programs operated by The Nature Conservancy, state Heritage Programs, and information available from preserves, parks, and protected natural areas would be a source of information on the locations and habitats of such species in the coastal zone.

EXOTIC AND INVASIVE SPECIES: Exotic and invasive species share the capability of capturing open or vulnerable niches. Purple loosestrife, hybrid cattail, Phragmites, zebra mussels, and exotic fish species are just a few types of biota in this large group that continue to invade the Great Lakes basin. Models of lake level variation should incorporate invasions of exotic / invasive species in scenarios when the potential for open niches emerge. In the coastal zone, reducing long-term lake level variation may have the effect of creating habitats with reduced native diversity. Existing expert information about the habitats and behavior of invading species would be useful in integrating exotic / invasive species types into habitat models.

WILD RICE: Wild rice is one of the few plants harvested in the coastal zone of the Great Lakes. In the upper Great Lakes basin, this is primarily an issue for Lake Superior. Wild rice (*Zizania palustris*) is harvested by the people of First Nations and Native American tribes and is one of the few plants in the coastal zone harvested as a food stock. Wild rice occurs in tributaries of the Great Lakes. This species, while adapted to annual cycles of water level variation, also depends upon long-term lake level variation for population sustainability. Wild rice, an annual species (grows from seed each year) cannot withstand invasion by other plant species, and depends on variation in lake level to maintain its habitat in a state of early succession. Little is known about how long-term lake level variation affects the population size of wild rice. Additional analysis of harvest rates and populations vs. lake level variation are needed. This is an important plant species that could be reduced if lake level variation is reduced. Resource specialists of the First Nations and tribes would be invaluable sources of data and experience on the relationship between wild rice populations, harvests, and lake level variation.

TOXIC CONTAMINANTS: If modifications of the outflow regime from Lake Superior are predicted to influence erosion or flow patterns in tributaries or coastal sites, there may be concern over increasing releases of contaminants from Areas of Concern or other industrial or urban sites. Of special concern is mercury and its toxic methylated products formed with exposure of contaminated sediment to air. Of concern also are other toxic substance releases from buried sediments, if fluvial or erosion patterns change under revised management. In considering the risk of outflow regulation-mediated changes in mixing and fluxes of contaminated sites, we need to understand population-level risks of toxins to aquatic life and aquatic-dependent wildlife. Fish and wildlife issues include life-stage effects, reproduction and mortality, along with food web bioaccumulation. Such analyses could transfer laboratory and local field results to regional landscape scales.

NUTRIENTS: Nutrients enter the Great Lakes from point and non-point sources, including urban, suburban, and rural runoff. Point sources of nutrients include discharges from wastewater treatment plants and stormwater outfalls. Nonpoint sources include runoff laden with fertilizers and manure and discharges from septic systems. Some nutrients first enter groundwater and then are discharged to the Great Lakes. Nutrients stimulate attached and planktonic algae, and so influence aquatic food webs and water clarity. Over-enriched, eutrophic waters can lead to elimination of SAV beds, problems with hypoxia, altered fisheries food webs, contaminated water supplies, and aesthetic problems. The relationship between annual and long-term lake level variation and groundwater discharge is poorly understood for Great Lakes coastal areas. Investigations of relationships between sources of nutrients and lake level variation should follow, if modeling scenarios predict significant alterations of flow regimes in tributaries or groundwater at the coastal zone interface. We also need to know how eutrophication and associated hypoxia affect basic food web support for commercial and recreational fish species and wildlife species of interest. Such work could include development of conceptual models from existing data and field studies in Phase 2, especially of groundwater and other non-point sources, as well as analyses of food web structure.

RISK ASSESSMENT: Techniques to assess the risk of threats to ecosystem integrity are developing, and are being incorporated into toxic effects analysis and monitoring programs. Decision-support tools can incorporate estimates of risk associated with effects of Lake Superior outflow regulation on various natural resources. In many but not all situations, risk can be apportioned among human-induced and natural components associated with stressors, such as contaminant releases, eutrophication, fish and wildlife population effects, and others. Risk assessment can put effects in perspective for decision-makers and for the public.

4.1.3 Tasks, Schedule and Cost

Ecosystem study aspects for Phase 1 would include the following tasks:

- Assess impacts of water level variations on the St. Marys River ecosystem, in particular, habitat for fish species, and provide input on guidelines governing flow variations in the St. Marys River at Sault Ste. Marie
- Acquire and synthesize, for purposes of analysis of lake level scenarios, existing data and expert opinion on the following ecosystem functions of coastal and nearshore habitats: wetlands and other coastal habitats for fish and wildlife, fisheries, colonial nesting birds, amphibians and reptiles, submerged aquatic vegetation, exotic/invasive species, wild rice, toxic contaminants, and eutrophying nutrients.
- Develop decision-support models to link water levels and flows with ecosystem information to have predictive capabilities to assess effects of various alternative regulation plans on ecosystems. Methods for model validation should be included. Incorporate existing bathymetry and topography for coastal ecosystems

where data are available, and make decision-support tools available to stakeholders.
- Enhance platforms for status and trend reporting and ways to incorporate status and trend information into decision support tools.
- Incorporate post-glacial lake level information (from USGS) into decision-support tools.
- Evaluate effects of alternative regulation scenarios on the ecosystem.
- Develop a risk assessment framework for use in evaluation of lake level responses by key features of ecosystems, as the scope of effects emerges during Phase 1.

Ecosystem study aspects of Phase 2 would include detailed studies of some of the above, if modeling and expert opinion in Phase 1 determines a high priority need.

The costs for the ecosystem evaluation in Phase 1 of the study, including salaries and travel, are estimated as follows:

	Year 1	Year 2	Year 3
Total Cost (U.S. dollars)	$400K	$1,300K	$400K
or			
Total Cost (Canadian dollars)	$600K	$1,950K	$600K

The total cost for Phase 1 of the study would be about $2,100K (U.S. dollars). This is equivalent to about $3,150K in Canadian dollars.

If Phase 2 is implemented, the costs for ecosystem evaluation could range from $700K to $1,500K (U.S. dollars). This is equivalent to $1,050K to $2,250K in Canadian dollars.

4.2 Recreational Boating and Tourism

Recreational boating and tourism are important economic industries in the Great Lakes states and in Ontario. The Great Lake Commission estimates that there are over a million recreational boats registered in U.S. counties that border the Great Lakes and nearly 800,000 in Ontario that are used on the Great Lakes (GLC, 2000). Boating on the Great Lakes is a popular recreational activity on both sides of the border. For example, of the 13.4 million boating days estimated in the state of Michigan in 1994, 4.8 million were spent on Great Lakes waters. Out of 3.9 million launches at access sites throughout Michigan, 1.4 million were at sites with access to the Great Lakes. The use of larger boats stored at Great Lakes marinas accounted for a third of boat-related spending, or between $200 million and $300 million in Michigan in 1994 (PZC, 2001).

The study of recreational boating and tourism in this study would include an analysis of sports and commercial fishing.

4.2.1 Relationship to Water Level Fluctuations

The recreational boating industry is greatly affected by water levels. Low water can adversely affect recreational boating in several ways. Direct effects include damages to boats, docks, and seawalls, and reduced accessibility as water levels drop. Accessibility is particularly a problem to properties that have water-only access, such as on eastern and northern Georgian Bay. Damage to boats can occur when boats run aground or hit submerged objects. Docks and seawalls exposed to air as water levels drop can start to decay, leading to accelerated deterioration and failure. Even high water levels can cause occasional problems, preventing passage under bridges, for example.
Although effects due to high and low water would both be addressed, most of the effects to recreational boating occur due to low water, so those would be a primary focus of the recreational boating effort. Indirect effects of low water on recreational boating include the loss of boat use and the resulting reduction in related spending. Marinas, boat launches, and related boater support services suffer when boating days are reduced either due to low or high water. Costs for dredging increase during low water periods as many marinas are forced to dredge just to stay in business. Facilities often have to be renovated or upgraded just to stay in business. Boat sales also suffer during periods of low water, as the perception of low water affects overall user interest in the industry.

Water-related tourism is likewise greatly affected by variations in water levels. Extreme high and low water levels can reduce business at marinas, waterfront restaurants, and other commercial establishments and increase costs of doing business. When access problems occur due to extreme high or low water levels, tourism in the coastal communities throughout the upper Great Lakes suffers.

4.2.2 Recreational Boating and Tourism Study Approach

In order to assess the effects of the current and alternative operating plans on recreational boating and tourism in the upper Great Lakes, a detailed description of current recreational boating use and tourism would be developed. A detailed recreational boating study is currently underway for Lake Michigan on the Lake Michigan Potential Damages Study. The recreational boating study on Lake Michigan will assess the economic effects of extreme low and high water levels on the recreational boating, sports fishery, marinas, and boat launching facilities. A similar study would be performed on Lake Superior, Huron, St. Clair, and Erie. In addition, the implications of changes to the Lake Superior regulation plan on tourism throughout the upper Great Lakes would be assessed.

The study approach entails the use of site visits, mail and phone surveys, focus groups, interviews, and mapping to collect and analyze data. The end result would include a wealth of never-before-gathered information about how Great Lakes water levels affect the tourism and recreation economic sectors and how the Lake Superior regulation plan can be modified to help the recreation and tourism industry on the upper Great Lakes. It would provide a tremendous amount of information that would also be useful to natural resource and recreation administrators at all levels.

The study would assess the current state of recreational boating and tourism on the upper Great Lakes and then project potential impacts due to alternative operating plans and climate conditions. The study would be designed similar to the study currently underway on Lake Michigan so that the Lake Michigan results can be used directly in this study. The low water level period that began in the late 1990s provides a useful basis of comparison when conducting the surveys. For example, the survey could be structured to identify any reduction in boating activity due to the recent low water levels. Boaters could then be asked how they might adjust their boating activity if water levels were reduced even further, with specific increments of water level reductions discussed.

The study on recreational boating and tourism would be conducted in six tasks. Details on each task are provided in the next section:

(1) Refine study method in consultation with U.S. and Canadian agency representatives, industry organizations, First Nations/Native Americans leaders.
(2) Analyze tourism, boating, and commercial fishing businesses and the relationship of their infrastructure to water levels on Lakes Superior, Huron, Michigan, St. Clair, and Erie.
(3) Integrate all data to report on the size and economic importance of coastal tourism, commercial and charter fishing, and recreational boating and the relationship of these resources to water level fluctuations.
(4) Conduct mail and telephone surveys of marinas, charter boats, boat dealers, boat repair and reconditioning facilities, boaters, and Great Lakes-dependent tourism businesses in Ontario and the states bordering the upper Great Lakes. Representative samples of registered boat owners would be developed to ensure the survey sample represents all sizes and types of boats and marinas.
(5) Integrate economic analysis on industries and Great Lakes economy to estimate the economic impacts of fluctuating water levels on recreational boating and tourism industry.
(6) Assess relative impacts of alternative regulation plans and make recommendations for any improvements to regulation plans specifically for the recreational boating and tourism industry.

A crucial element of the survey task is to develop and test the surveys that would be given to the recreational boaters, marinas, dealerships, and charter fishing boats. The survey would be designed to obtain a representative sample of boat types and sizes as well as marina types and sizes. These questionnaires would be developed and tested to ensure the accuracy of the survey questions and to increase the robustness of the information to be provided through the completion of these questionnaires. Information gathered from previous studies would be utilized in the design and testing of these survey instruments.

Once an assessment of the recreational boating use on the lakes is complete, the results of the survey can be used to develop a relationship between water levels and boater days. The economic information collected through the surveys would also be used to develop an average cost expended per boater day. Using these relationships, the relative impacts of alternative regulation scenarios on recreational boating can be evaluated. Although

this approach does not develop a computerized "model" to predict economic impacts of different water levels, it is appropriate for determining relative impacts between alternative regulation scenarios and has been used successfully for the same purpose on Lake Michigan.

Impacts on tourism would also be addressed in this study. Impacts would be limited to those directly related to fluctuating water levels, such as effects on waterfront commercial districts that are inaccessible during high water levels. Conversely, effects could also include impacts on businesses in small waterfront communities during low water periods that make their marinas inaccessible or reduce the attractiveness of waterfront facilities for visitors and customers.

4.2.3 Tasks, Schedule and Costs

The recreational boating study for Phase 1 would include the following tasks, following the six major tasks identified above:

Task 1—Refine Study Method

- Identify and meet with industry organizations and First Nation/Native American leaders to gain support for the study.

Task 2—Analyze tourism, boating, and commercial fishing businesses

- Inventory boat launch ramps and channels supporting recreational boating and determine relationship to water levels (i.e., at what water level does the ramp/channel become inaccessible). This needs to be done for Lakes Superior, Huron, St. Clair, and Erie. The Lake Michigan inventory is available from the LMPDS work.
- Compile and verify lists of marinas and recreational watercraft dealerships in the upper Great Lake states and Ontario.
- Obtain and analyze lists of registered boat owners in upper Great Lakes states and Ontario, including the proportion and type of boats registered and/or stored in coastal counties/regions.
- Prepare for and conduct focus groups with boating administrators and boating industry representatives regarding boating infrastructure.
- Identify tribal and non-tribal commercial fishing and charter fishing businesses with business infrastructure on or dependent on the upper Great Lakes. Estimate the economic significance of the industry relying on secondary data, including reported landings of fish, employment, and business activity.
- Conduct meetings with First Nations/Native Americans and non-tribal commercial fishing interests, charter captains, and fishing guides.
- Identify and describe prominent coastal tourism attractions and businesses, including coastal heritage attractions, resorts, cruise and dive boat operations, water trails, eco-tourism, downtown waterfront tourism complexes.
- Identify four representative tourism dependent coastal communities/locations where there is a concentration of waterfront tourism businesses and attractions and

develop maps showing the shoreline at a potential range of water levels.

- Prepare and conduct meetings with tourism officials in the four locations. Include tourism association representatives and tourism business owners to explore how water levels affect their businesses.
- Use available secondary data from U.S. and Canada to estimate the size of the tourism industry and the economic significance of tourism in the upper Great Lakes coastal counties and municipalities. Identify prominent upper Great Lakes-dependent coastal tourism communities and businesses.

Task 3—Integrate data

- Integrate inventories, economic significance information and focus group results. Report on the size and economic importance of coastal tourism, commercial and charter fishing, and recreational boating. Also report on the relationship of these industries to water level changes. Use this information to focus surveys to be conducted in Task 4.

Task 4—Conduct surveys of marinas, charter boats, boat dealers, boaters, and tourism businesses

- Assess the performance of previous mail and telephone surveys of marinas and dealerships conducted in Michigan in two previous low-water related studies
- Develop separate customized telephone and mail survey instruments for marinas, dealerships, and recreational boaters. The surveys would focus on coast and revenue impacts of fluctuating water levels, economic significance of these businesses on the upper Great Lakes economy, and methods and investments to mitigate the impacts of fluctuating water levels. Survey of marinas would request the optimal water level range for operation as well as high and low levels beyond which operation would be severely affected.
- Survey of recreational boat owners would focus on the impacts of water levels on the amount of boating and the location/duration of their boating; also include infrastructure and access issues. Include questions of access at high water levels and range of satisfactory levels, indicating the high and low levels at which serious problems are expected to occur
- Revise survey instruments based on pre-test of the instruments and reviews by U.S. and Canadian administrators and industry representatives.
- Conduct surveys and perform analyses.
- Integrate findings with dealer and marina focus group results.
- Conduct mail survey of registered boat owners, using representative samples of boat owners with an emphasis on boaters in Great Lakes coastal counties and regions.
- Conduct survey of coastal tourism businesses on the upper Great Lakes to determine the relationship of water levels to their businesses including methods being employed to mitigate impacts, and the expenses incurred.

Task 5—Integrate economic analyses on industries and economy

- Use survey results to estimate the direct revenue and cost impacts of fluctuating

water levels on boating businesses, commercial and charter fishing, livery and dive boats, and tourism businesses.
- Estimate spending impacts on the upper Great Lakes of reduced boating and/or reallocated boating-related spending.
- Use this information, along with the survey results and secondary information, as input to economic input-output models developed for the LMPDS to estimate the economic impacts of varying water levels.

Task 6—Assess relative impacts of alternative regulation plans
- Analyze infrastructure inventory, focus group results, and survey results in relationship to water levels.
- Identify any potential changes to Lake Superior regulation plans that would enhance recreational boating and tourism in the upper Great Lakes.
- Assess relative impacts of alternative regulations plans compared to current regulation plan on recreational boating.
- Develop guidelines for design of new facilities to adapt to fluctuating water levels to enhance operations and reduce damage/inconvenience.

The costs for the recreational boating and tourism evaluation in Phase 1 of the study, including salaries and travel, are estimated as follows:

	Year 1	Year 2	Year 3
Total Cost (U.S. dollars)	$250K	$250K	$250K
or			
Total Cost (Canadian dollars)	$375K	$375K	$375K

The total cost for Phase 1 of the study would be about $750K (U.S. dollars). This is equivalent to about $1,125K in Canadian dollars.

The need for additional study in Phase 2 is questionable for the recreational boating study. The methods outlined in Phase 1 should be sufficient to characterize impacts of regulation changes. No additional Phase 2 detailed studies are anticipated.

4.3 Hydropower

4.3.1 Existing Facilities

There are two hydroelectric power plants located on the United States side of the St. Marys River. The U.S. Government Hydropower Plant consists of a plant completed in 1951 together with a smaller unit that is the remnant of a larger plant originally built in 1888. The other U.S. plant, which was built in 1902, is operated by Edison Sault Electric Company. In Canada, Great Lakes Power Limited retired its older station and constructed a new plant in 1982. In accordance with IJC Orders, after the requirements for domestic use, navigation, and St. Marys Rapids (including the fishery remedial works) are met, the

remaining outflow from Lake Superior is shared equally between Canada and the United States for hydropower purposes. Any remaining flow allotment that exceeds the discharge capacity of the hydropower plants is normally released through the compensating works.

Since the redevelopment of the Canadian facilities in 1982, the total installed hydropower capacity on the St. Marys River has been increased. It is doubtful that there will be any significant hydropower expansion in the future. However, given the age of the station, eventual redevelopment of the Edison Sault facilities should be considered in the review of the regulation criteria. Equipment upgrades in the future are expected to marginally improve the efficiencies of these plants.

There are no hydropower facilities on the St. Clair and Detroit Rivers. Several hydropower plants are located at Niagara Falls, New York and Ontario. These plants divert water from the Chippawa-Grass Island Pool above Niagara Falls, and return the water to the Niagara River below Niagara Falls. The amount of water available for hydropower purposes at these plants depends on the Niagara River flow which, in turn, depends on the water level of Lake Erie. The initial phase of the study would be focused more on the hydropower generation on the St. Marys River, where changes to Lake Superior regulation would have the greatest impact on hydropower operations. If , however, potential changes to Lake Superior criteria and regulation plan were expected to have measurable impacts on Lake Erie and its outflows, the study would be extended to include impacts on hydropower facilities at Niagara.

4.3.2 Relationship to Water Level Fluctuations

The amount of hydropower generation on the St. Marys River depends on several factors, the key ones being:

- *Head:* vertical distance that water falls across the hydropower dam; the greater the fall, the more hydropower can be generated.
- *Flow:* amount of water that drives the turbine, which, in turn, drives the generator.
- *Efficiency:* percentage of the potential energy of the water transformed to electrical energy.
- *Tailwater:* Due to its design, excessively low water levels below the Edison Sault plant could severely affect operations.
- *River Ice and Aquatic Growth:* Ice upstream or downstream of the hydropower dam could reduce the flow capacity of the dam, in some circumstances leading to reduction in hydropower generation. Aquatic growth is not considered a problem in the St. Marys River.
- *Meteorological Disturbances:* Rapid changes in air pressure and storms can cause large short-term changes in the water levels at the hydropower dam.

Apart from these physical factors, there are other elements that affect hydropower operations. The first element is timing. In some years, the water available for

hydropower production in June may not generate as much monetary return as the same water in January when electrical demand is typically higher. On the other hand, hydropower would be a premium during a heat wave in June. When the flows are too low, the electricity generated may not meet the demands of the customers and the utilities may have to purchase power from other sources at relatively higher price. The purchased power may be generated by coal, oil, or nuclear. Therefore, the purchasing power would involve transfer of monetary benefits and may have environmental implications. The move to an open market system means that reliability of water is essential for both long- and short-term planning purposes.

Relatively high water levels on Lake Superior means relatively higher flows, as directed by the regulation plan. This translates into more electricity generated. Relatively low water levels on Lake Superior would bring about the opposite condition. When the water available for hydropower purposes exceeds the capacities of the plants, the excess is typically discharged into the St. Marys Rapids via the compensating works, and thus represents a loss to hydropower generation. Extended periods of equipment shutdown at the plant could also lead to additional water released at the compensating works.

To meet energy demand, which varies within the day and within the week, the hydropower plants in the St. Marys River carry out peaking operations. In peaking operation, the plants pass high flows during the daylight hours (when energy demand is high), which are offset by lower flows during the night and on weekends. These operations take place when the water allocated for hydropower purposes are less than the flow capacity of the hydropower plants, and thus typically take place when Lake Superior's water levels and outflows are below average. While beneficial to the hydropower interests, these flow variations have caused concerns by the navigation, fisheries, and other interests in the St. Marys River. The concerns become more pronounced during low water level and flow conditions in the river. It is recommended that priority be given to address this issue. The impacts of peaking operations would be assessed early in the Phase 1 study, which would provide input to development of guidelines governing these operations, subject to confirmation at the completion of the study.

4.3.3 Tasks, Schedule and Costs

For Phase 1, the tasks would include the following:

- Evaluate in energy and monetary terms the impacts of peaking operations; provide inputs in developing guidelines governing peaking operations.
- Project hydropower facilities for the study period; determine their flow capacities and generating efficiencies.
- Update, and develop as required, evaluation methods that determine the relationships between energy production and flows.
- Investigate, and adapt wherever suitable, other evaluation techniques including those used in the Lake Ontario - St. Lawrence River Study.

- Assist in identifying changes to regulation plans to improve operation.
- Evaluate the impacts of Lake Superior outflow regulation under a range of alternative regulation and supply scenarios, including those generated by global climate change models.
- Assist in writing reports, attend study board meetings, and meetings of other study teams.

Fairly sufficient information is available to evaluate the hydropower effects due to alternative regulation plans. Therefore, no extensive data collection efforts are required. The costs for the hydropower evaluation in Phase 1 of the study, including salaries and travel, are estimated as follows:

	Year 1	Year 2	Year 3
Total Cost (U.S. dollars)	$100K	$150K	$150K
or			
Total Cost (Canadian dollars)	$150K	$225K	$225K

The total cost for Phase 1 of the study would be about $400K (U.S. dollars). This is equivalent to about $600K in Canadian dollars.

The scope and level of details in the Phase 2 study would depend on the findings from the Phase 1 study. If Phase 1 finds that only relatively minor changes to the Lake Superior regulation plan would provide overall net benefits to all the users in the system without causing significant adverse impacts on any one interest, then no further major tasks are anticipated. The remaining work would include refinements to the regulation criteria and the plan, documentation of study results, report writing, etc. On the other hand, if Phase 1 finds that more detailed study would be required to answer the questions and the issues raised in the IJC directive, then, additional studies and evaluation including extensive data collection efforts may be required.

Based the discussion above, the cost of Phase 2 could take one to two additional years, with corresponding estimated costs from $200K to $250K (U.S. dollars), which is equivalent to roughly $300K to $375K in Canadian dollars.

4.4 Commercial Navigation

4.4.1 Existing Facilities

Using the Great Lakes – St. Lawrence River navigation system, waterborne freight is transported both within the Great Lakes and between much of North America and overseas. The present system of locks and channel deepening was completed by the early 1960s. At that time, channels provided an available depth of 8.2 meters (27 feet) over the entire route from Montreal in the St. Lawrence River to Lake Superior. A series of locks

enables vessels to bypass rapids and other barriers in the St. Lawrence River between Montreal and Lake Ontario. Likewise, locks in the Welland Canal enable vessels to transit between Lake Ontario and Lake Erie, bypassing Niagara Falls. In the St. Marys River, there are four navigation locks in the United States, and one lock in Canada enabling vessels to transit between Lake Superior and Lakes Michigan and Huron.

Subsequent channel improvements have led to the present available depths:

St. Marys River	8.2 – 9.1 m (27 – 30 feet)
St. Clair River	8.2 – 9.1 m (27 – 30 feet)
Lake St. Clair	8.4 m (27.5 feet)
Detroit River	8.4 – 9.0 m (27.5 – 29.5 feet)
Welland Canal	8.2 m (27 feet)

The focus of this study would be on the water levels and flows of the upper Great Lakes from Lake Superior through Lake Erie. However, it should be recognized that vessels affected by water levels on the upper lakes (for example vessels carrying lighter loads to compensate for low levels in connecting channels) could be affected on their trans-Atlantic and other global trade routes. In addition, there are other factors that could have impacts on water levels and flows, and Lake Superior regulation, and vice versa. A recent study prepared for the St. Lawrence Seaway Development Corporation titled *Economic Impact Study of the Great Lakes St. Lawrence Seaway System* would provide useful information on economics related to the commercial navigation industry.

In 1959 when the current Seaway system was near completion, ships with drafts no deeper than 6.86 meters (22.5 feet) were allowed to transit the St. Lawrence River. This allowed for vessel under-keel clearance and squats. Through dredging, technological advances, and operating experience, the allowable vessel draft has been successively increased to 7.92 m (26 feet) in 1970. When water level conditions are favorable, the Seaway agencies in both countries have in recent years allowed ships to transit with drafts up to 8.0 m (26.25 feet). Studies are currently underway by Seaway agencies to examine the feasibility of permitting vessels requiring 8.08 m (26.5 feet) draft.

In 1999, the U.S. Congress authorized a study (the Great Lakes Navigational System Review) to determine the feasibility of improving commercial navigation on the Great Lakes system, including locks, dams, harbors, ports, and channels and other related features. If capital improvements appear to be warranted, more detailed feasibility studies could follow. The first phase of this study, called the Reconnaissance Phase, is just about underway.

The U.S. Congress also authorized the U.S. Army Corps of Engineers in 2000 to carry out dredging in federal channels, harbors, and the connecting channels of the Great Lakes to ensure minimal operation depths consistent with the original authorized depths of the channels and harbors when water levels in the Great Lakes are, or are forecast to be, below the International Great Lakes Datum of 1985. No dredging under this authority has taken place to date and there are currently no plans to do so. This study would only

assess the potential impacts of new proposed dredging, or any other structural changes to the system, if there is a high likelihood that such changes will occur.

4.4.2 Relationship to Water Level Fluctuations

Generally, higher water levels allow for deeper draft vessels carrying heavier loads. At lower water levels, shallower drafts, and consequently, lighter loads, are necessary. More trips are needed to carry the same tonnage of cargo, and some per ton operating expenses rise accordingly, to the disadvantage of the shipping industry. Excessively high water levels would not bring additional benefits since vessel sizes are limited by existing lock dimensions. Very high water levels could flood some dock facilities, and generate undesirable and hazardous water currents in the connecting channels.

Ice on the Great Lakes and in the connecting channels can severely hamper navigation transits. It is not uncommon to see severe ice jams in the St. Clair and Detroit Rivers that last for days or even weeks. The ice problem is much less frequent or pronounced on the St. Marys River, due to the use of an ice boom. A severe and prolonged winter can cause significant problems at times of opening or closing of the navigation season.

One factor that affects navigation interests is flow variations at the hydropower plants at Sault Ste. Marie. The high flows during daytime and weekdays at the hydropower facilities cause higher levels in the vicinity of the Soo locks and channels immediately downstream of Sault Ste. Marie, which could be beneficial. However, the offsetting lower flows at night and on weekends cause lower levels and could delay ship transit and affect cargo capacity. This problem is more pronounced during low water level periods. Shippers also need to know in advance accurate forecast of water levels to plan their short-term and long-term routes. Accurate advance water level information helps planning and increases operating efficiency.

Much of the study can take advantage of the data, forecasts and evaluation methods currently generated in the Lake Ontario - St. Lawrence River Study. These would be reviewed to determine whether they are applicable to this study. Because of the many inherent economic assumptions made in the forecast and evaluation calculations, particularly regarding monetary values which are subject to change, the evaluation of impacts of water level fluctuations should not be conducted in terms of purely economic values.

4.4.3 Tasks, Schedule and Costs

For Phase 1, the tasks would include the following. The POS team assumes that some of this information may already be available from commercial navigation resources and agencies:

- Project Great Lakes–St. Lawrence navigation facilities for the study period, including planned dredging projects and capital investments that have a high likelihood of occurring (not just planned or discussed).

- Project cargoes and routes and make an assessment of the relationship between navigation service and other means of transportation (air, rail, pipeline, and truck).
- Determine applicability of existing transportation and evaluation models.
- Formulate assumptions concerning fuel costs and other operating costs.
- Update, and develop as required, the relationships between transportation costs and water levels and flows.
- Investigate, and adapt wherever suitable, other evaluation techniques.
- Identify changes to regulation plans or criteria to improve operations for navigation and navigation interests.
- Identify the impacts on navigation due to level and flow variations in the St. Marys River, identify critical water level locations in the St. Marys River, provide input in developing guidelines governing hydropower operations; identify remedial measures including improvements in communication and scheduling of ship transits.
- Evaluate the effects of alternative regulation and supply scenarios on navigation and navigation interests, including flooding under high level conditions and deterioration of timber crib/pile under low level conditions.
- Assist in writing reports, attend study board meetings and meetings of other study teams.

Assuming this study would make use of much of the data and evaluation methods generated in the Lake Ontario - St. Lawrence River Study, the costs for the commercial navigation evaluation in Phase 1 of the study, including salaries and travel, are estimated as follows:

	Year 1	Year 2	Year 3
Total Cost (U.S. dollars)	$150K	$150K	$150K
or			
Total Cost (Canadian dollars)	$225K	$225K	$225K

The total cost for Phase 1 of the study would be about $450K (U.S. dollars). This is equivalent to about $675K in Canadian dollars.

The scope and level of details in the Phase 2 study would depend on the findings from the Phase 1 study. If Phase 1 finds that only relatively minor changes to Lake Superior regulation plan would provide overall net benefits to all the users in the system without causing significant adverse impacts on any one interest, then no further major tasks are anticipated. The remaining work would include refinements to the regulation criteria and the plan, documentation of study results, report writing, etc. On the other hand, if Phase 1 finds that more detailed study would be required to answer the questions and the issues raised in the IJC directive, additional studies and evaluation including extensive data

collection efforts may be required.

Based on the discussion above, Phase 2 could take one to two additional years, and have a total estimate cost ranging from $400K to $600K (U.S. dollars), which is equivalent to $600K to $900K in Canadian dollars.

4.5 Municipal, Industrial, and Domestic Water Uses

4.5.1 Relationship to Water Level Fluctuations

In general, municipal and industrial water intakes are not greatly affected by fluctuating water levels on the upper Great Lakes system. Most, if not all, intakes are located at depths well below the historical range of water levels recorded in the previous century. Record low water levels occurred in the mid-1920s on Lake Superior and in the mid-1960s on Lakes Michigan-Huron. All major municipal and industrial water intakes built subsequent to these low water levels are most likely designed to accommodate at least these record lows; investigations in Phase 1 would verify whether this is the case.

Low water levels, however, could lead to problems including increased pumping costs, poor water quality in some areas, increased turbidity which can be worsened by passing boats and commercial vessels, algae growth and decay, and higher water treatment costs. Very low water levels predicted by some of the global climate models may render some of these intakes ineffective or completely inoperable. High water levels, on the other hand, may flood water treatment facilities that are located on flood prone coastlines.

Outside the urban centers, shore-wells are the source of water for many cottages, campers, and permanent homes along the shores of the upper Great Lakes. Shore-wells are generally not built to accommodate the total historical range of water level fluctuations due to lack of regulatory oversight and excessive costs. Again, if the low water levels predicted by some of the global climate models actually occur, many shore-wells would be affected to the point of complete shutdown.

This study can make use of the data and evaluation methods being generated in the Lake Ontario - St. Lawrence River Study. However, the potential changes to Lake Superior outflow regulation and the magnitudes of the associated changes in water levels of the upper Great Lakes are not known at this time. Therefore, it is premature at the initial stage of the study to embark on a costly field survey of all the large and small intakes for the entire upper lakes basin. Nonetheless, at a minimum, a fairly comprehensive inventory of the major urban and industrial intakes, especially those relatively more vulnerable to water level fluctuations, should be made. Much of this inventory data is already available from state or provincial agencies. For example, the U.S. Environmental Protection Agency is conducting a source water assessment in all Great Lake states. All major water intakes have been documented. Invert elevations for many of these intakes are also available through this data collection effort. Any additional information that is needed can be obtained by letter and telephone communications and if needed, followed

by visits to the critical sites. During this data collection effort, information on future basin needs for municipal and industrial water supply can also be obtained, if available.

Consideration should be given to pilot studies, using representative urban and rural centers, to assess the relationship between these facilities and water level changes under various Lake Superior regulation and climate change scenarios. At a minimum, the assessment would be made in terms of additional energy and other resources that would be required to maintain the current and forecast levels of service as a result of changes to Lake Superior regulation. There should also be other qualitative assessments, such as water quality, aesthetics, risk to public health, etc. If it is determined that more detailed evaluation is required, then a more complete inventory of the municipal and industrial water intakes and treatment plants, and their nature of operation, would be initiated.

Future basin needs for municipal and industrial water would also be addressed. This information would be closely coordinated with the future land use changes in the basin, as discussed in Section 4.7.

4.5.2 Tasks, Schedule and Costs

For Phase 1, the tasks would include the following:

- Use existing state and provincial agency inventories to identify major municipal and industrial intakes, including those vulnerable to extreme water level fluctuations.
- Compile current municipal and domestic uses; estimate future expected water demands, in terms of quantity and quality.
- Assess the effects of the current regulation plan on these water uses, assuming present and future use projections.
- Conduct pilot studies designed to provide more detailed assessment, if necessary, using selected urban and rural areas.
- Visit selected sites to collect data, if necessary.
- Investigate, and adapt wherever suitable, evaluation techniques.
- Assist in identifying any changes to regulation plans to improve operations to benefit municipal, industrial, and domestic water uses.
- Evaluate the effects of alternative regulation and supply scenarios on municipal, industrial, and domestic water interests.
- Assist in writing reports, attend study board meetings, and meetings of other study teams.

The costs for the municipal, industrial, and domestic water use evaluation in Phase 1 of the study, including salaries and travel, are estimated as follows:

	Year 1	Year 2	Year 3
Total Cost (U.S. dollars)	$150K	$200K	$200K

or			
Total Cost (Canadian dollars)	$225K	$300K	$300K

The total cost for the municipal, industrial, and domestic water use evaluation Involvement Program for Phase 1 of the study would be about $550K (U.S. dollars). This is equivalent to about $825K in Canadian dollars.

The scope and level of details in the Phase 2 study would depend on the findings from the Phase 1 study. If Phase 1 finds that only relatively minor changes to Lake Superior regulation plan would provide overall net benefits to all the users in the system without causing significant adverse impacts on any one interests, then no further major tasks are anticipated. The remaining work would include refinements to the regulation criteria and the plan, documentation of study results, report writing, etc. On the other hand, if Phase 1 finds that more detailed study would be required to answer the questions and the issues raised in the IJC directive, then, additional studies and evaluation including extensive data collection efforts may be required.

Based the discussion above, Phase 2 could take one to two additional years, with corresponding estimated costs ranging from $100K to $250K (U.S. dollars), which is equivalent to $150K to $375K in Canadian dollars.

4.6 Coastal Zone Impacts

Coastal Zone in this plan of study includes the shore zone and lands adjacent to the water that are either under private or public ownership. Fluctuating water levels affect the coastal zone in all of the lakes under consideration in this study. Coastal impacts include erosion and flooding along the coast and impacts due to low water levels. These impacts affect shore property values and thus result in economic damages. Long-term maximum and minimum water levels, when combined with short-term seiche or surge/drawdown impacts, can cause substantial damage to coastal resources.

4.6.1 Relationship to Water Level Fluctuations

Fluctuating water levels affect most coastal zone interests either directly or indirectly. High water levels can combine with storm waves or ship wakes to cause serious flood and erosion damage. Low levels increase the shore area, but can also affect water intakes, ramp and docking facilities, and water quality, and can lead to the undercutting of shore protective works. This issue was studied in the recent IJC Levels Reference Study (IJC, 1993).

The results from the surveys conducted in the Levels Reference Study indicate that erosion is the most common problem for riparians on the Great Lakes and the St. Lawrence River. However, damage is largely confined to beaches, lawns and gardens for non-native riparians, while native communities also experience erosion damage to boat launch facilities and roads. A relatively small percentage reported erosion damage to

dwellings.

The Levels Reference Study generated stage-damage curves to estimate the potential changes in dollar values of flood and erosion damage to residential, commercial, industrial and public property, and public infrastructure. The curves were based on curves developed from damage surveys and damage payments made during the 1970s. The curves were updated to 1991 values to take into account inflation, new development, moving or removal of structures, and construction of shoreline protection. The curves were used to evaluate regulation plans including those listed under Measure 1.21. These data are obsolete and should not be used for this study.

Following the Levels Reference Study, and in response to recommendations made by the IJC, the Detroit District of the U.S. Army Corps of Engineers (USACE) initiated the Lake Michigan Potential Damages Study (LMPDS) in 1996 to provide an extensive assessment of potential shoreline damages due to changes in Lake Michigan water levels over the next 50 years (USACE, 2000). To a very limited degree, some of this work was followed up by the Buffalo District of the U.S. Army Corps of Engineers in the Lower Great Lakes Erosion Study, which began in 1998. This study was designed with the goal of developing a tool to assess local and regional impacts associated with coastal projects on Lakes Erie and Ontario (Stewart, 1999).

No recent comparable basin-wide effort has been initiated on the Canadian side of the upper Great Lakes. A number of shoreline Conservation Authorities and local Ontario Ministry of Natural Resources Districts have developed comprehensive shoreline management plans for addressing the flooding and erosion issue, which may be of great benefit in pursuing damage reduction.

The results obtained on the LMPDS, the Lake Ontario - St. Lawrence River Study, and the Canadian/Ontario Shore Damage Survey should be reviewed to determine if the information and methods could be used to infer relative impacts of flooding and erosion due to water level changes on coastal areas of the upper Great Lakes. For example, detailed coastal erosion modeling has been conducted on five counties on Lake Michigan as part of the LMPDS project. The counties included areas of high cohesive bluff environment as well as sandy, dune environments. Detailed bathymetric and topographic data, historical bluff lines, and physical features were collected for these five counties.

4.6.2 Coastal Zone Impacts

Due to its geologic setting and the relatively sparse urban development, flood and erosion damage on the Canadian shores of Lake Superior is relatively minor compared to that on the U.S shores or on the other Great Lakes. On the Canadian shores, the major urban centers affected by both high and low water levels are Thunder Bay and Sault Ste. Marie, Ontario. Numerous campsites, marinas and boat docks, cottages (some year-round) are located along the shores of Lake Superior, Lake Huron including Georgian Bay, and the St. Clair – Detroit River system. The Canadian shores of Lake Erie consist of mainly low-lying farmland in the western portion, and a combination of farms, cottages and small urban and industrial centers further to the east. Studies during the Levels Reference Study found that, in Canada, the highest incidence of erosion has occurred on Lake Erie.

The eastern coast of Georgian Bay is unique in its features. By size alone, it could be considered a lake in itself. However, unlike other bays on the Great Lakes, it is geologically, hydrologically, geomorphologically, and limnologically unique. Because of the shallow waters around the 30,000 islands, Georgian Bay is greatly affected by changes in water levels. There are few scattered wetlands due to the steep granite shoreline. When water levels change, wetlands have difficulty migrating due to the steep nearshore environment.

Information gathered from recent public meetings and discussions with experts indicate that Georgian Bay, while a hydrologic part of Lakes Michigan-Huron, has a unique environmental (including wetland) and socio-economical setting that is sensitive to water level fluctuations. The first phase of the study should assess the impacts of various water levels on Georgian Bay by a conducting site-specific or pilot study. As a minimum, a literature search should be made to identify the locations, nature, and extent of the concerns from shoreline property owners and interests concerning high and low water levels.

The U.S. side of the upper Great Lakes differs from the Canadian coastal zone in several key areas. Population on the U.S. side is much greater than on the Canadian side. The potential for coastal damages is much higher. The U.S. portion of the upper Great Lakes coastal zone also contains more shoreline area and more areas that are subject to active erosion and flooding. Coastal erosion and flooding are a particular concern in the high bluff environment of Lake Michigan, the far western shores of Lake Superior, and select areas on Lake Erie. Previous studies have identified shore type and recession rates along all the Great Lakes. In addition, the LMPDS project is currently working to identify coastal areas that are critically sensitive to water level changes, which should help focus this study to specific coastal areas that are most likely to be affected by alternative regulation plans.

Pilot studies are recommended in the initial phase of the study. For selected sites, the causes and effects of fluctuating levels should be investigated. An evaluation method, for example, water level vs. impact curves, should be developed to assess the relative merits of different regulation plans. The study should address the impacts on these sites if the

long-term mean water levels under regulation were to be raised or lowered. In Canada, potential sites include the eastern township of Thunder Bay, Sault Ste. Marie and sites on the lower St. Marys River, on Georgian Bay, at Sable Beach, and at Port Elgin. Sites on Lake Erie would also be included, with the level of detail depending on the magnitude of water level impacts due to Lake Superior outflow regulation. On the U.S. side, potential interest areas would include Duluth, Whitefish Bay, and a select area on each of Lakes Michigan, Huron, St. Clair, and Erie.

Investigations on Lake Michigan should take advantage of the detailed analyses conducted during the LMPDS. The coastal processes model established for five coastal counties on Lake Michigan under the LMPDS could be used for investigation in Phase 1 of this study. The models were developed using detailed bathymetric and topographic data, historical bluff line analysis, and coastal feature collection. The coastal processes model for these five counties could be run with water level scenarios from alternative regulation plans to assess the relative effects of the alternative plans on coastal erosion in these representative regions on Lake Michigan. This could be valuable in determining how much, if any, additional data collection and analysis is warranted in Phase 2. If there is little relative difference in coastal erosion predicted under various alternative regulation plans for these five counties, or if the predicted differences in erosion rates is within the margin of error of the models, further intensive data collection to support detailed coastal modeling would not be recommended.

If more detailed studies are required, they could include development of accurate erosion and flood prediction models. This would be a very large undertaking since it would require extensive field data collection and a thorough understanding of shoreline geology, coastal structures, sediment transport, environmental conditions such as wind and wave effects, water currents, vegetation, and ice cover on the Great Lakes and their connecting channels. Added to these would be projections of urban and rural developments on the shores. All of these components must be integrated and linked to translate sequences of water level and flow into flood and erosion predictions, either in some physical terms or in monetary terms. This detailed analysis, if deemed necessary, would be conducted on site-specific areas in Phase 2.

4.6.3 Tasks, Schedule and Costs

For the initial phase of the study, the tasks would include the following:

- Conduct a literature review of past flood and erosion concerns.
- Conduct site-specific visits to gather additional information.
- Consult riparian representatives, experts, and land-use planners on desirable ranges of water levels.
- Assess the impacts on coastal zone of the lower St. Marys River due to flow variations at Sault Ste. Marie, provide input to developing guidelines governing hydropower operations.
- Develop water level – impact relationships or other alternatives such as stage-

damage curves, erosion sensitivity vs. water level or flooded buildings vs. water level curves to compare regulation plans.

- Review and assess effectiveness of existing land use regulations at protecting coastal zone interests from water level related damages.
- Conduct pilot studies for detailed assessment of impacts of water levels [note—pilot study could consist of using the detailed modeling results developed on Lakes Michigan and Ontario and develop a strategy to apply the results to similar shore environments, thus maximizing use of previous work and reducing amount of detailed modeling necessary for Phase 1; consider modeling five Lake Michigan counties under alternative regulations plans].
- Develop new stage-damage curves and other evaluation techniques.
- Assist in identifying any changes to regulation plans that could minimize coastal resource impacts.
- Assist in writing reports, attend study board meetings and meetings of other study teams.

The costs for the coastal zone evaluation in Phase 1 of the study, including salaries and travel, are estimated as follows:

	Year 1	Year 2	Year 3
Total Cost (U.S. dollars)	$250K	$400K	$350K
or			
Total Cost (Canadian dollars)	$375K	$600K	$525K

The total cost for the coastal zone evaluation in Phase 1 of the study would be about $1,000K (U.S. dollars). This is equivalent to about $1,500K in Canadian dollars.

If the studies conducted in Phase 1 do not provide sufficient information on effects on coastal resources, Phase 2 would be initiated on a targeted basis. For the second phase, where more detailed analysis is required, the tasks could include expansion of the work in the first phase for a limited number of critical areas, including the following:

- field data collection of topographic and bathymetric data in select areas
- shore geomorphology and sediment transport studies
- inventory and assessment of level of protection of existing shore development and shore protection
- incorporate projections of future urban development and land use trends
- collect, and develop where necessary, climate data, ice and aquatic growth data, under present regime and those of climate change
- develop evaluation models relating water level changes with erosion processes
- establish assumptions for economic analysis to generate impacts, in monetary or other qualitative terms, of impacts of water level fluctuations under various regulation plans and climate change

While extensive data collection and studies are taking place in the U.S. for some counties on Lake Michigan, no comparable efforts for any other lakes are underway or expected to proceed in the near future. Data collection and development of evaluation models are expected to be the major costs. The two more additional years of study effort could cost in the range of $2M to $3.5M in U.S. dollars ($3M to $5.25M in Canadian dollars).

4.7 Future Basin Land Use Changes

The IJC directive requested that the POS address whether changes in the regulation plan are warranted to meet contemporary and emerging needs, interests and preferences for managing the system in a sustainable manner, including under climate change scenarios. In order to assess whether changes to the regulation plan would be needed to meet emerging needs, these emerging needs must be defined. Demographic and land use changes and shifts will likely continue to occur in the basin. Water needs will change along with them. Climate variability and changes due to anthropogenic effects will also affect net basin supplies in the future. Climate variability is discussed in Section 4.8, Hydrologic and Hydraulic Evaluation.

4.7.1 Demographics

Demographics would play an important role in assessing future basin changes and needs as they pertain to future demand for consumptive water uses. In addition, demographic changes that result in increased shoreline development could affect the nearshore environment. When shoreline protection is constructed, natural sediment transport processes are altered, and erosion of barrier beaches and coastal wetlands increases. Increases in population can result in construction of new highways near the lakeshore or across floodplains. Where these highways cross riverine wetlands adjacent to the lake, flow restrictions under bridges or through culverts also disrupt sediment transport processes and can result in excessive siltation in wetlands or alter hydrologic processes. Encroachment can result in direct loss of nearshore environment and chemical contamination of that environment.

Census projections, future demographic trends and projections would be used to estimate potential demands on the basin. The Great Lakes Commission is currently leading a study that lays the framework for future water use decisions. This study, the Water Resources Management Decision Support System, is developing a decision support mechanism to evaluate impacts of future water demands on the resources of the basin. The data, tools, and methods collected in this study should be used to the maximum extent practical in the Upper Great Lakes Study.

A recent study by the IJC assessed the impacts of existing diversions and consumptive uses (IJC, 2000). This study would be used to the maximum extent to fully utilize the recent work conducted in this area.

Future basin demands would be incorporated into supply scenarios as evaluated in the

hydrologic and hydraulic modeling effort, which is described in detail in Section 4.8.

4.7.2 Physical Changes to System

There are many ongoing studies that are considering future basin needs and potential infrastructure changes that would be necessary to satisfy these future needs. Many of these studies are listed in Section 3.2 of this document. To the extent that any of these physical changes become highly likely to occur, this study would address the impacts of those changes on levels and flows in the system.

For example, the U.S. Army Corps of Engineers is currently conducting a Navigation Review, which is assessing the infrastructure needs of the navigation system within the Great Lakes. If that review indicates a high likelihood of physical changes to navigation channels, locks, or other physical structures—changes likely to affect flows and levels on the Upper Great Lakes—the study described here would include investigation of the consequences of such changes.

4.7.3 Land Use Issues

In Phase 1, a review should be made of the existing land use management practices, including zoning, and the effectiveness of existing regulations designed to minimize flood and erosion damage. Over the upper Great Lakes region within this study area, there are many unique and important coastal segments and complexities of ownership and jurisdiction. For example, Ontario has a planning area called the Heritage Coast that includes about one million hectares of land intermingled with private lands and 18 First Nations reserves.

This study would focus on pilot areas, which would be chosen based on a number of factors:

- There is a history of risk due to changing water levels or information that would suggest higher risk.
- There is more information available than for other shoreline communities or areas, such as land use, demographic and economic data.
- There is sufficient population and development at risk or with interests in water level relationships to warrant study.
- There is a unique ecosystem relationship to water levels.

Within the pilot areas, qualitative information gathering would focus on assessing the response of local communities to dramatic past water level changes and evaluating how well they have planned for future changes in Great Lakes levels. The impacts of land use on the ecosystem of the Great Lakes would also be included in the discussions held with the pilot communities.

4.7.4 Tasks, Schedule, and Costs

Phase 1 tasks would consist of the following:

- Conduct a literature review of riparian risk and land use trends along the upper Great Lakes from Lake Superior through Lake Erie.
- Collect socio-economic data and trend information for the upper Great Lakes coastal areas from both the U.S. and Canada.
- Identify seven pilot study areas in which to concentrate data collection and contact with riparians and officials. The seven target areas would include one on each lake plus three additional areas to cover different physiographic, development, and planning variations. Examples include Thunder Bay and Sault Ste. Marie on Lake Superior, Georgian Bay and the Michigan thumb on Lake Huron, and a north and south shore Lake Erie site. Information on Lake Michigan can be gathered from LMPDS efforts.
- Gather master plans and zoning ordinances of upper Great Lakes waterfront communities in the pilot areas. Also include existing land use maps, air photos, and other sources of information on land use.
- Hold discussions with riparians regarding their experiences and perceptions of the impacts of water level changes and the roles of government agencies in responding to changing water levels. These discussions would also seek to develop water level-impact relationships.
- Discuss with local and regional officials regarding their experiences and perceptions of the impacts of water level changes on their communities and the services they provide. These discussions would also seek to develop water level-impact relationships.
- Compile all data gathered into GIS mapping; analyze background data to determine potential relationship between water level changes and land use development patterns, considering risk and water level-desirability relationships. This analysis would include consultation with one or more economists.
- Assist in identifying changes to regulation plans and evaluating effects of alternative regulation plans.
- Assist in writing reports, attend study board meetings and meetings of other study teams.

The costs for the future land use evaluation in Phase 1 of the study, including salaries and travel, are estimated as follows:

	Year 1	Year 2	Year 3
Total Cost (U.S. dollars)	$100K	$100K	$100K
or			
Total Cost (Canadian dollars)	$150K	$150K	$150K

The total cost for the future basin land use changes evaluation in Phase 1 of the study

would be about $300K (U.S. dollars). This is equivalent to about $450K in Canadian dollars.

No further land use change evaluations are anticipated in Phase 2. The information on future land use would be sufficiently defined in Phase 1.

4.8 Hydrologic and Hydraulic Evaluation

4.8.1 Hydrologic and Hydraulic Models

The evaluation of Lake Superior regulation plans, the practicality of proposed criteria, and the hydrologic impacts on the interests, require computer simulation of water levels and flows. Computer models currently exist, including a recently developed Canada-U.S. Coordinated Great Lakes Regulation and Routing Model (CGLRRM). This model incorporates the Lake Superior regulation plan and hydraulic outlet conditions of the St. Clair, Detroit, and Niagara Rivers and Great Lakes diversions. The model computes water levels and flows of the upper Great Lakes including Georgian Bay and their connecting channels through Lake Erie and the Niagara River, given historical water supplies or other supply scenarios. In addition to outflow regulation study, the model can be a useful tool in assessing the impacts of dredging, diversions, and climate variability.

A user-friendly model is currently being developed for the Lake Ontario regulation study. Such a model is an educational tool that can be used interactively or at public meetings. The model can be designed to compute Great Lakes water levels and outflows given certain simplified assumptions such as water supplies, changes in the regulation plan, or regulation strategies with certain objectives. It is proposed that a similar user-friendly model be made applicable for the upper Great Lakes.

Throughout the study, the hydrologic and hydraulic resource committee would generate the water level and flow scenarios and distribute to the other resource committees, including the evaluation committee, for analysis.

Due to the size and response time of the upper Great Lakes to water supplies, the Lake Superior outflows are regulated on a monthly basis. Most historical water supply data are also developed on a monthly basis. Thus, for the testing and hydrologic evaluation of regulation plans, and for climate change studies, levels and flows would likely be computed on a monthly basis using the regulation plan and supply routing model discussed above. With this time step, it is possible to ignore short-term effects such as those caused by winds and transients set up by flow changes.

To examine short-term water level effects, for example, daily or weekly flow changes at Sault Ste. Marie, detailed hydraulic models would be needed to simulate changing water levels and flows of the St. Marys River. The U.S. Army Corps of Engineers, Detroit District is beginning work on developing a one- and a two-dimensional hydrodynamic model of the St. Marys River. The study team should investigate the availability of this

model at study inception to determine if this would be a feasible tool in Phase 1 of the study. Such a model would be required to investigate impacts of dredging and other factors in the St. Marys River

The subject of flow variations (peaking operations) has been discussed in previous sections including Sections 4.3 and 4.4. An assessment of the water level impacts would be first carried out through analysis of water level data from recent years, followed by applications of hydraulic models.

There are also other hydrologic models, such as the hydrologic prediction and basin runoff models developed and operated by GLERL. To examine the impacts of climate change, the results of the studies of global climate models described in Section 4.7 would be used as variable net basin supply scenarios.

4.8.2 Great Lakes Water Supply Scenarios

4.8.2.1 Existing Climate

Lake Superior Regulation Plan 1977-A was developed and tested using 1900-1986 historical water supplies to Lake Superior and the downstream lakes, adjusted to certain assumptions concerning water diversions and outlet conditions of the downstream lakes. Since 1986, more extreme supplies have been recorded. These include the rapid decline in the water supplies in 1987-1988, the very high supplies of the mid 1990s, and the very low supplies that began in the late 1990s. The first step in this study would be the updating of the historical water supplies through the year 2001 and defining other basic parameters in the modeling such as diversions, outlet conditions, and ice and aquatic growth impacts on flows.

Periods of higher and lower water supplies will occur in the future due to the natural variation in climate, even without the effects of anthropogenic increases of greenhouse gases in the atmosphere. To design a regulation plan that would be more useful under a wider range of supplies, consideration would be given to generating synthetic hydrologic sequences based on the statistical properties of existing historical supply using, for example, a stochastic approach. Some work in this area should be carried out in the first phase of the study, with more detailed analysis in the second phase, if deemed necessary.

Some consideration should also be given to the recent work on projecting annual lake level fluctuations over the past 4,700 years (Baedke and Thompson, 2000). This research suggests that there is a quasi-periodic behavior in supplies at two different scales. It may be possible to incorporate these findings into the development of synthetic monthly hydrologic sequences, which would be needed to evaluate alternative regulation plans. In addition, this work may provide insight in developing supply sequences that simulate climate variability.

4.8.2.2 Climate

Resource Committees will be expected to communicate routinely with each other and to share efforts (for instance GIS data, hydrologic scenarios, climate forecasts, etc). Since the end result is to balance and optimize the benefits to all resources, good coordination and cooperation between the study committees is critical. The Board-appointed study managers will ensure cooperation and communication among the study committees and seek efficiency where resources can be shared. Variability and Anthropogenic Climate Change

The climate of the upper Great Lakes basin has a great impact on the requirements and effectiveness of the Lake Superior outflow regulation plan. Net basin supply, defined as runoff into the lake plus precipitation directly onto the lake minus evaporation from the lake, is a function of climate. Net basin supply sets a hard upper limit to the amount of water that can be stored in or released from a lake. The net basin supply has had historical variations on many timescales, and is expected to have a systematic trend due to anthropogenic climate change superimposed on the natural variability in the future.

A qualitative assessment of changes due to demographic and other possible factors would be made to illustrate how such changes may affect water supplies and related hydrologic factors. Alternative basin supplies could then be routed through the hydraulic model to determine the impacts on levels and flows.

Summary of past and current studies

Climate variability has resulted in variability in lake levels on the Upper Great Lakes during the period for which gage records exist. The utility of observed time series of lake levels has been enhanced by the use of stochastically generated time series of net basin supply which were used to produce a 50,000-year synthetic time series of lake net basin supplies with statistical characteristics similar to those of the observed time series (Lee, et al. 1994). This is a useful method for synthesizing time series of net basin supply as input to a hydraulic routing model and calculating frequency of exceedance of various lake levels under scenarios corresponding to experimental lake regulation plans.

Baedke and Thompson (2000) reconstructed high stand levels of Lake Michigan over the past 4700 years, which can also be transformed into a long time series of net basin supply, and input into a hydraulic routing model. They have demonstrated that a 160-year cycle in lake levels exists concurrently with a 30-year cycle, both of which they believe to be related to climatic factors. A similar reconstruction is pending for Lake Superior levels.

A major existing resource for anticipated changes in lake levels due to anthropogenic climate change is the Great Lakes/Midwest Regional Assessment under the U.S. Global Change Research Program (Lofgren, et al. 2002). Projections of departures of future mean lake levels from the present (averaged over decadal time scales) primarily show drops in the levels of all of the Great Lakes. In the most recent studies, these reductions in mean lake levels are greater over Lakes Michigan, Huron, and Erie than over Lake Superior, to a maximum of 1.38 m (4.53 feet) by the year 2090. On the other hand, one general circulation model (GCM) simulating future anthropogenic climate change

predicts an increase in precipitation large enough to overpower the expected increase in evaporation from the lakes and the surrounding drainage basin, resulting in a slight rise in mean lake levels (maximum of 0.35 m or 1.15 feet by 2090). This range of uncertainty calls for a regulation plan that is adaptable.

The Canadian Country Study, published in 1998, reached many conclusions similar to the Great Lakes/Midwest Regional Assessment with regard to the influence of climate change on the water levels of the Great Lakes. The GCM-based studies that were referenced at that time were entirely consistent in projecting a drop in lake levels due to greenhouse warming. This study also highlighted the possible increase of strong episodic runoff events, and the impact of this on the Great Lakes. This impact is primarily in the rivers tributary to the Great Lakes, because the lakes' large volume buffers them from sudden lake level variations due to episodic events.

Current understanding and gaps

The Great Lakes drainage basins have the ability to store ground water for gradual release into river systems tributary to the Great Lakes (base flow). The lakes also have very large lake surface areas. These two factors contribute to the long response time of the upper Great Lakes, particularly Lakes Superior, Michigan, and Huron, is long. Natural climatic anomalies that occur at timescales less than a few years have strongly attenuated response in terms of changes in lake level, while lake level variability is apparent on the approximately 30-year cycle seen in the gage records and on the 160-year cycle seen in the paleo-records.

In addition to the uncertainties already noted in the predictions of GCMs over spatial scales as large as the basin of any of the Great Lakes and multi-decadal averaging periods, the reliability of GCMs diminishes with decreasing spatial and temporal scale. Variability of precipitation at time scales on the order of a few years can have decisive impacts on lake levels. This is also the time scale of modes of natural variability such as El Niño-Southern Oscillation (ENSO), which are often inadequately reproduced by GCMs. Simulated temporal trends in the range of climate variability within a GCM (i.e. statistical non-stationarity) are particularly suspect. For these reasons, researchers have avoided analysis of trends in variability as predicted by GCMs. Also, analysis on spatial scales corresponding to the distance between the individual Great Lakes approaches the limit of the resolution of GCMs. This means that spatial variation in the output of the GCMs among the lakes could have a large component attributable to artifacts of the numerical methods used in the simulation.

There may be other region-specific atmospheric factors affecting water levels that we do not yet understand. For example, it has been pointed out that air quality monitoring results around Georgian Bay show ozone forming early in the day and remaining until late in the evening. As a result, it is possible that the exposed granite shoreline may heat up early in the day and hold the heat into the evening. If so, evaporation rates on Georgian Bay could conceivably be uniquely affected. It would clearly be well beyond the scope of this study to attempt to fill this and similar gaps in knowledge. Nevertheless, any reliable

and relevant research results that come available during the course of the study should be taken into account.

Proposed studies and methodology

Rather than assessing variability as depicted by GCMs, it is likely to be more fruitful to attempt to gain greater understanding of the long-term variability of the past, whose modes are likely to be extended into the future. This includes the relationship between climatic variables and lake levels at time scales from a few years to a few decades and an understanding of the manifestations and causes of common variability of climate and lake levels at timescales of a few years to several decades. The long-term modes of variability involve regimes of wet-cold, wet-warm, dry-cold, and dry-warm conditions, which are connected to large-scale, persistent atmospheric circulation patterns. These circulation anomalies have been characterized by teleconnection indices, such as ENSO, the North Atlantic Oscillation (NAO), the Pacific Decadal Oscillation (PDO), and others. Empirical matching of combinations of the magnitudes and phases of these indices with the precipitation-temperature regime of the Great Lakes region would be carried out, leading to enhanced physical understanding of the causes of teleconnections between the climate of the Great Lakes region and foci of oceanic forcing.

Aside from attempts at greater understanding of the teleconnective forcing of climate regimes, scenarios of net basin supply can be generated by extension of observed net basin supply through stochastic synthesis of a long time series, and also through reconstruction of paleo-levels. The former method can be directly implemented in the Upper Great Lakes. The latter method has already yielded data relative to Lakes Michigan and Huron, and would be greatly aided by the development of data from Lake Superior.

Regarding anthropogenic climate change, in addition to the more mature GCM methodology for anticipating the climatic effects of increased greenhouse gases, the regional climate modeling (RCM) approach is gaining feasibility and reliability. Like the GCM, this approach uses a model of atmospheric dynamics and physics based as much as possible on first principles of fluid dynamics, boundary-layer diffusion, atmospheric radiative transfer, plant physiology (for moisture and heat transfer from soil and plants), etc. Also like the GCM, it relies on upper and lower boundary conditions of incident sunlight and surface properties (which can also be incorporated as part of a surface-atmosphere coupled model). Unlike a GCM, an RCM also depends upon prescribed lateral boundary conditions in the atmosphere, which are usually supplied by a GCM. The advantage of the RCM approach is that it resolves finer spatial detail of a single region, thus taking more complete account of the presence of lakes and the resultant mesoscale flows and recycling of water evaporated from lakes and precipitated again into the same lake's drainage basin. Its disadvantages are the large amount of computational resources required, the resultant short duration of feasible model runs, the dependence on possibly unreliable GCM data as lateral boundary conditions, and the matching of lateral boundary conditions to internal model conditions.

Additional analysis patterned on the previous use of GCM data but based on more current, and presumably more accurate, GCM results (namely, the Hadley Climate Centre Model version 3) would also be undertaken. All of these climate-related studies would be coordinated with hydraulic studies, with the outputs from the climate studies being used as input for channel routing and lake regulation models.
Scenarios for future climate-related patterns and trends in levels of the Upper Great Lakes will be incorporated into decision-support tools for analysis of the influences of natural vs. regulated variation on coastal ecosystems and impacts to other interests.

4.8.3 Review Existing Regulation Plan, Investigate New Techniques

Plan 1977-A, the regulation plan presently used in Lake Superior outflow regulation, takes into consideration the water level conditions on both Lake Superior and Lakes Michigan-Huron in determining the flows in the St. Marys River. The plan has worked fairly well striving to balance the needs of the users both upstream and downstream, while aiming to manage Lake Superior's levels within a specified range. However, Lake Superior levels outside the specified range would occur regardless of the regulation plan, given the extreme water supplies experienced in the past and those expected to occur in the future, especially under climate change. Nonetheless, operating experience has identified some potential changes to the plan that warrant further investigation.

During the recent Levels Reference Study, a number of changes to Plan 1977-A were investigated, including those under Measure 1.21. As described in Section 1.1.5, the Levels Reference Study Board selected Measure 1.21 as the most promising alternative. As a minimum, Measure 1.21 should be updated and its impacts on levels and flows evaluated along with other regulation techniques.

Plan 1977-A is based on the principle of systemic regulation, and uses prescribed water level and other hydrologic parameters for Lake Superior and Lakes Michigan-Huron in specifying monthly Lake Superior outflows. As part of Phase 1, the evaluation would include a review of available hydrologic forecasting techniques. More accurate long-term forecasts of water supplies may lead to better, more responsive regulation plans and decision-making. A review of regulation techniques and forecasting techniques are currently being carried out in the Lake Ontario - St. Lawrence River Study and may produce results applicable to this study.

Other technical improvements to Plan 1977-A would include review of the balancing equation, use of the updated outflow equation for Lake Erie, review of the forecasting procedure in the plan, update to the hydrologic parameters and side channel capacities, and updates to assumptions regarding ice and aquatic growth impacts. While these changes are not expected to bring about significant impacts on levels and flows, they should be investigated as a part of the study.

4.8.4 Lake Superior Pre-Project Outlet Conditions

To compare water level and flow conditions under regulation to those that would have

occurred without regulation, a model of the pre-project or unregulated Lake Superior outlet hydraulic relationship would be used. This can be done with the CGLRRM, which is already developed and used by the U.S. Army Corps of Engineers and Environment Canada. Levels and flows under pre-project conditions are essential, particularly for assessing impacts on resources throughout the basin, including coastal ecosystems. The results obtained would also facilitate the consideration of options consistent with systemic regulation, but which would result in mean levels and variability closer to that in the state of nature. This state of nature regime of water levels and flows is also essential for all the resource committees to assess the impacts of a regulation scenario that simulates pre-regulation or pre-project conditions (levels and outflow assuming no hydropower and navigation developments).

The routing of water supplies would assume existing downstream hydraulic outlet conditions in the St. Clair and Detroit River system. If necessary, the routing of supplies could include assuming St. Clair – Detroit River outlet conditions prior to the major dredging projects of the 1930s and 1960s. A fairly comprehensive hydraulic analysis would be needed to accurately determine the stage-outflow relationships for the St. Clair – Detroit River system prior to these projects.

4.8.5 Evaluation of Regulation Plans and Criteria

The IJC directive asked for a review of the operation of the structures controlling the outflows of Lake Superior, which at present is governed by Plan 1977-A. Therefore, the base case for evaluating scenarios in this study would assume Plan 1977-A as the plan of regulation, along with current hydraulics and hydrology, including diversions and channel hydraulics and outlet conditions.

Since the needs and preferences of the various interests are different, and at times in opposition, development of a comprehensive set of criteria and a matching regulation plan satisfying all the interests would not be a simple task. There is a need to demonstrate what levels and flows are physically possible with the current physical regulatory works and channels, through simulation of regulation for the wide range of possible hydrologic conditions. An understanding of the reality and practicability of certain level or flow conditions could help promote better dialogue amongst the interest groups and the acceptance of the needs of others and the eventual needed compromise among the groups. This would be an iterative process likely involving workshops, public meetings, and regulation plan development and testing.

As a start, the needs and preferences of all the users should be defined in some minimum level of detail. A modified Plan 1977-A, new regulation plan(s), and levels and flows under Lake Superior pre-project outlet conditions would be developed and evaluated to determine to what degree they meet the user needs and existing regulation criteria. The impacts of climate changes on existing and proposed regulation plans would also be evaluated. Others variables that could be assessed using the regulation and supply routing models would include dredging, diversions, consumptive uses, etc.

The hydrologic evaluations would be fairly detailed. However, the assessment of impacts on the interests would be generally qualitative. In some cases, quantitative impacts would be generated (for example, hydropower and navigation). From these, further technical adjustments to the regulation plans may be possible to arrive at the best possible regulation plan given the user needs and physical constraints. Potential changes to the existing regulation criteria can then be identified.

If the needs and impacts of regulation cannot be clearly defined with the available data and analyses in Phase 1, and there appears to be potential benefit from changing regulation, then Phase 2 would be required. Methods for conducting detailed evaluations would be developed and data collection programs designed to ensure they produce the needed data.

4.8.6 Diversions, Consumptive Uses, Groundwater, Land Use and Dredging

The impacts on Great Lakes water levels and outflows due to existing major water diversions would be updated using the CGLRRM. The most recent estimate of consumptive uses would be updated. The impacts on Great Lakes water levels and flows due to current and projected consumptive uses would be determined. A qualitative assessment of the relationship between Great Lakes water levels and groundwater flows would also be made. A qualitative assessment would be made of the impacts on Great Lakes water levels and flows due to changes in land use, such as urban development and de-forestation.

The impacts of past dredging in the St. Clair – Detroit River system on water levels and flows would be summarized. This would include literature search and a review of past dredging projects, study of hydrographic charts and sounding data, and computer hydraulic simulation. The study would also explore remedial works and their effectiveness in offsetting the hydraulic effects of past dredging.

4.8.7 Tasks, Schedule and Costs

For the first phase, the tasks would include the following:

H&H Evaluation

- Assess the impacts on water levels of the St. Marys River due to peaking operations by hydropower plants at Sault Ste. Marie, develop interim guidelines governing peaking, taking into consideration the needs and concerns of other resources; develop hydrodynamic model for more detailed study and refine operating guidelines.
- Update historical water supply sequence through current year.
- Establish pre-project Lake Superior outlet conditions (utilizing the historical supply sequence), and determine resulting water levels and outflows in all lakes and connecting channels, assess water level impacts of past outflow regulation.

- Qualitatively assess impacts of future basin water needs and land use changes on water levels and flows.
- Investigate relationship between groundwater and levels and flows.
- Summarize documented impacts on levels and flows of past and current dredging activities.
- Summarize the impacts of man-made changes in the Niagara River (e.g., installation of hydropower works and fills in the river) on Lake Erie water levels.
- Investigate and incorporate technical changes to Plan 1977-A, alternative regulation techniques, and hydrologic forecasting improvements.
- Generate levels and flows under the base case, using Plan 1977-A.
- Generate levels and flows under pre-project conditions.
- Develop regulation scenarios to address user needs/preferences of water level/flow ranges and frequencies; generate levels and flows for these scenarios.
- Generate water levels and flows for alternative regulation plan(s) under potential climate change/variability scenarios; recommend regulation plan improvements to enhance their adaptability under changed climate conditions.
- Develop user-friendly interactive computer model for Great Lakes regulation
- Write reports, attend study board meetings and meetings of other study teams.

Climate Variability

Because much of the climate variability study overlaps with investigations related to the IJC's Lake Ontario - St. Lawrence River Study, cost estimates are dependent on the amount of cost-sharing that can be arranged with the Lake Ontario - St. Lawrence River Study. Close coordination on climate studies is being developed with the Task Group for Hydrology and Hydraulics of the Lake Ontario – St. Lawrence River Study. Phase 1 studies would include historical variability and teleconnections, RCM modeling, and further GCM analysis. For the initial phase of the study, the tasks and schedule would include the followings:

RCM modeling:

- In year 1, complete run and analysis of current version of Coupled Hydrosphere-Atmosphere Research Model (CHARM) for time periods centered at 1990, 2030, and 2095; begin test runs using IBIS land surface scheme to represent soil/vegetation evaporation and runoff.
- In year 2, complete testing of CHARM with the inclusion of the IBIS scheme and inserting a distributed lake surface temperature and ice cover model.
- In year 3, execute improved model for time periods centered at 1990, 2030, and 2095 and analyze results. Use these results to calculate net basin supply for each lake, and provide this as input to hydraulic studies.

Further GCM analysis

- In year 1, acquire output from Hadley Centre Climate Model Version 3

(HadCM3). Use as input to GLERL runoff and lake evaporation models to calculate net basin supply for lakes. From this, changes in mean lake levels can be derived under current standard assumptions. These net basin supplies can be retained for later reanalysis of lake levels under altered hydraulic scenarios.

- Compare model results to USGS results from field coring and other historic data; incorporate hindcast and forecast scenarios for climate-driven levels and flows into various analyses for other resources, such as coastal ecosystems, navigation, etc.

The costs for the hydraulics and hydrologic evaluation (including climate variability) in Phase 1 of the study are estimated as follows:

	Year 1	Year 2	Year 3
Total Cost (U.S. dollars)	$700K	$400K	$400K
or			
Total Cost (Canadian dollars)	$1,050K	$600K	$600K

The total cost for the hydraulic and hydrologic evaluation in Phase 1 of the study would be about $1,500K (U.S. dollars). This is equivalent to about $2,250K in Canadian dollars.

The scope and level of detail in the Phase 2 study would depend on the findings from the Phase 1 study. If Phase 1 finds that only relatively minor changes to Lake Superior regulation plan would provide overall net benefits to users in the system without causing significant adverse impacts on any one interest, then no further major tasks are anticipated. The remaining work would include refinements to the regulation criteria and the plan, documentation of study results, report writing, etc. On the other hand, if Phase 1 finds that more detailed study would be required to answer the questions and the issues raised in the IJC directive, then, additional studies and evaluation including extensive hydrologic evaluation would be required. No additional climate variability work is anticipated for Phase 2.

Based the discussion above, the cost for hydrologic and hydraulic evaluations in Phase 2 could take one to two additional years, with corresponding estimated cost range of $900K-$1,200K (U.S. dollars) or $1,350K to $1,800K in Canadian dollar equivalent.

On the hydrologic and hydraulic evaluation, Environment Canada and the U.S. Army Corps or Engineers are expected to be able to provide some in-kind services. However, the exact amount is unknown. The costs presented here assume a moderate level of in-kind support from these agencies.

4.9 Development of an Evaluation Methodology

A sound evaluation methodology identified early in the process and used to guide

decisions on study design is critical to the success of the overall study. The evaluation methodology would be used to characterize and assess impacts associated with various water level and flow scenarios. The methodology must be able to measure effects on non-economic resources such as ecosystems so that evaluations can consider effects on all resources. The committee may consider developing a set of performance indicators to assist in evaluating effects of alternative regulation plans on each of the resource areas. The indicators should address for each resource common parameters associated with Lake Superior outflow regulation. Such parameters could include timing of water level/flow changes, annual and seasonal level and flow averages and variations, recovery potential, and adaptability of the resource to various temporal scales of water level fluctuations. Trade-offs must be made, considering basin-wide and cumulative effects on hydropower, navigation, recreational boating and tourism, ecosystems, and water use. Trade-offs and balancing even within one resource area must be considered when evaluating regulation changes on such a large geographic area. Using the parameters suggested above, the study team could determine which short-term impacts may be reasonably acceptable if they occurred at a certain time or if the affected resource could adapt to the changes, thus minimizing impacts.

The evaluation methodology is so critical that the POS team recommends that an evaluation committee be established at the outset of the project. The evaluation committee would include, at a minimum, one member from each of the resource committees. In addition, the chair of the evaluation committee should have access to expertise in decision support technology, which would be very helpful in establishing the methodology for making regulation decisions. The evaluation committee would be formed at the start of the study and would define its evaluation methods and data needs at the study outset, which would help focus the work of the individual resource committees.

The costs for the evaluation methodology committee for Phase 1 of the study, including salaries and travel, are estimated as follows:

	Year 1	Year 2	Year 3
Total Cost (U.S. dollars)	$200K	$200K	$200K
or			
Total Cost (Canadian dollars)	$300K	$300K	$300K

The total cost for the evaluation methodology evaluation in Phase 1 of the study would be about $600K (U.S. dollars). This is equivalent to about $900K in Canadian dollars.

Phase 2 costs would be approximately $600-1,000K (U.S. dollars) or $900K to $1,500K converted to Canadian dollars.

5. STUDY ORGANIZATION

5.1 Study Management

Given the multi-disciplinary nature of the study, it is proposed that a Study Board be set-up to direct the work of the study teams. The Study Board would be responsible for the conduct of the study; the Board would ensure that study objectives are met, that work is focused on meeting study objectives, that schedules are maintained, and that funds are allocated in a timely and logical manner. The Board would be composed of an equal number of members from Canada and the United States who would be appointed by the Commission to serve in their personal and professional capacities. A Study Board that is too large can become unwieldy, which reduces effectiveness. The POS team recommends that the Study Board consist of 6 to 8 people, with and even number of representatives from each country. The Board members should be experts in the fields related to this study with the experience and ability to understand and take an objective approach to scientific/technical information.

The Board should assign two study managers, one from Canada and one from the U.S., to manage day-to-day operations of the study. The Study Board would then establish specific binational technical resource committees that would be responsible for conducting the individual studies for their particular resource, using the available expertise of the two nations. Potential agencies that have the necessary expertise for these individual studies are listed in Annex 1.

Prior to the conduct of the study and expenditure of funds, the roles and responsibilities of the Board, the study managers and resource committees would be clearly defined. It is expected that, like the Lake Ontario study, the IJC would seek government funding for the study. The funding obtained by the IJC would be used to help fund Board operations --for example travel, communication, and contract work. Government agencies in Canada and the United States may provide some in-kind support of their expert staff.

Resource committees will be expected to communicate routinely with each other and to share efforts (for instance GIS data, hydrologic scenarios, climate forecasts, etc). Since the end result is to balance and optimize the benefits to all resources, good coordination and cooperation between the study committees is critical. The Board-appointed study managers will ensure cooperation and communication among the study committees and seek efficiency where resources can be shared. The study organization chart is shown in Figure 2.

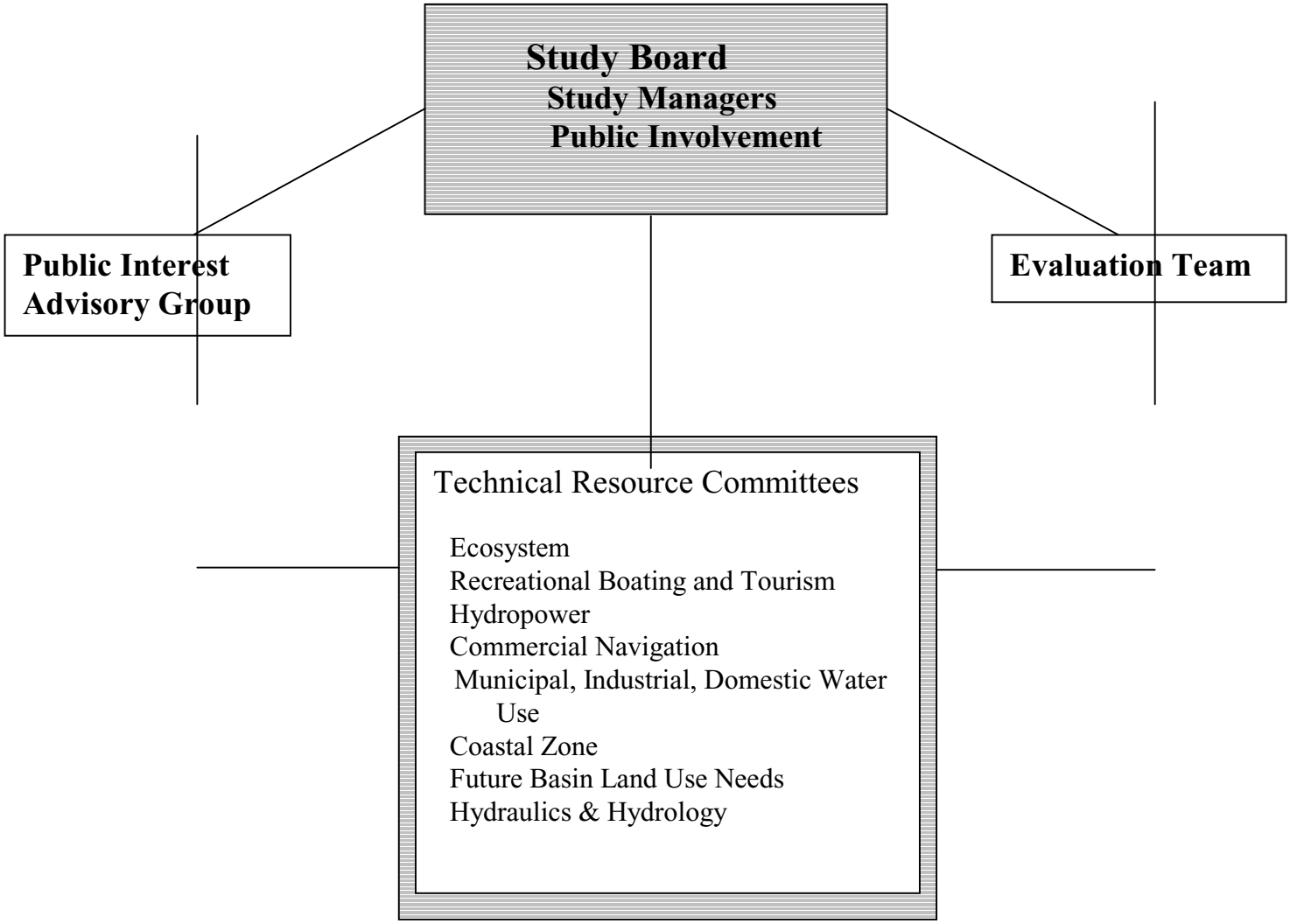

Figure 2
Upper Great Lakes Study Management

The authority and tasks of the board would include:

a. Appoint appropriate technical resource committees and approve work plans of the committees.
b. Review and approve evaluation methods and data collection programs.
c. Approve specifications and costs of professional service contracts, with the management of contracts assigned to the study managers. Work with the IJC to obtain government funding approval for the full duration of the study to minimize delays and disruptions. Consider forming a binational joint account for the study. This would reduce complications due to the different fiscal years between the two countries and would lead to a more efficient and timely study results.
d. Oversee the work progress of study teams to ensure they are on schedule and to ensure that the work incorporates an ecosystem approach, which is supported by the Commission.
e. Act as coordinator to ensure effective exchange of information among the study teams, and full use of studies or information from other sources.
f. Consult the Lake Superior Board of Control on regulation and operating experience.
g. Conduct public meetings to gather information related to water level fluctuations.
h. Consult with experts on the subject of climate change and climate variability.
i. Propose a method of integrating the needs of all the various users including taking recreational boating and ecosystem needs into consideration, while respecting the requirements of the Boundary Waters Treaty and particularly its Article VIII.
j. Review and propose updated regulation criteria based on tasks above, while respecting the requirements of the Boundary Waters Treaty, particularly its Article VIII.
k. Recommend improvements to the Lake Superior regulation plan.
l. Prepare progress reports and a final report to the International Joint Commission.

In addition, the magnitude and complexity of the studies and work outlined in this Plan would require a full time manager in each country, the costs for which have been included in the overall Study Management figures (refer to Tables 1 and 2).

It is proposed that the Study Board would meet twice a year, or more often if required to evaluate progress. Each of the Committees' evaluating interests would meet more frequently and provide monthly status reports to the Study Board. Progress reports would be provided to the IJC on a semi-annual basis. The Study Chairpersons would also be available to brief the IJC at their semi-annual hearings in Washington and Ottawa.

The committees and other groups associated with the study would also be composed of an equal number of members from Canada and the United States who would serve the Commission in their personal and professional capacities. Committee members would be selected from various entities, as suggested in Annex 1.

The costs for study management for Phase 1 of the study, including salaries and travel, are estimated as follows:

	Year 1	Year 2	Year 3
Total Cost (U.S. dollars)	$400K	$400K	$450K
or			
Total Cost (Canadian dollars)	$600K	$600K	$675K

The total cost for study management in Phase 1 of the study would be about $1,250K (U.S. dollars). This is equivalent to about $1,875K in Canadian dollars.

Phase 2 costs would be approximately the same, $1,250 (U.S. dollars) or $1,875K Canadian.

5.2 Committees

It is anticipated that one of the first actions of the Study Board would be to establish specific technical work groups or resource committees that would be responsible for study design using the scope, methods, and tasks discussed in Section 4. The technical resource committees would use the available expertise of the two nations and allocate resources accordingly. As is recommended in Section 2.2, early public involvement would also be critical, and the Interests Advisory Group would be established at an early date as well.

Committees would be created for each of the "interests" identified in Section 4 of this POS, in each case comprising a binational team from the various agencies with potential participation of the groups listed in Annex 1. Scheduling of their work would need to be coordinated through the Study Board.

It would be the task of the overall Study Board, with input from each committee and the Interest Advisory Group, to then consider the recommendation from the evaluation committee and bring this forward for public discussion of the impacts and benefits of various regulation plans and criteria. The Board, with assistance from the various study committees, should also assess how the current Orders, or any recommended changes to them, are carried out.

It is important that all interested parties understand that the study is not expected to be simply one of adding one or two regulation criteria. Since the needs of the users are different and divergent, conflicts among the criteria would invariably surface. As noted earlier, the challenge of the study is to promote understanding and acceptance of what is feasible given current institutional arrangements and control facilities. The process leading to new criteria and/or improvements to the regulation plan would include iterations in defining possible changes, meeting with user groups, and meetings with the Commission, which may itself result in consultations with governments.

Through the evaluation and study process, it is likely that a number of trial regulation plans would need to be developed and considered by the Study Board to allow the effects of any new or revised criteria or other regulation plan changes to be described in a manner that the Interest Advisory Group, general public, and the Commission can fully appreciate. While criteria may be stated in a number of ways, including upper and lower limits of levels or flows or restrictions on the frequency of exceeding certain conditions, their impacts and impacts of regulation plan improvements can only be appreciated once they are used to frame a new regulation plan. The outcome can then be tested using historic data so as to allow comparisons against previous experience. The costs of this work is contained within the various components of the "Hydrologic Model and Evaluations" as shown in Tables 1 and 2.

Upon completion of the evaluation process, the Study Board, again with input of the subject matter experts on the committees, the Interest Advisory Group, and the general public, would then report to the Commission regarding the work carried out, its recommendations on any amendments or additions to the present criteria, and the recommended regulation plan to give effect to these criteria. The Board should also report to the Commission the team's assessment regarding how the current Orders, or any changes to them, are carried out. The Commission, in turn, may wish to hold further public consultations prior to any decision to adopt, or otherwise respond to, the Study Board's recommendations.

5.3 Schedule and Cost Estimate

The Study as outlined in this POS would consist of two Phases. Phase 1 would be completed in three years. If, at the completion of Phase 1, the Study Board determines that more detailed data collection and analysis are required, Phase 2 would be implemented. Phase 2 would last an additional one to three years.

5.3.1 Phase 1

The proposed study for the review of regulation of outflows from Lake Superior has been designed to obtain the optimal amount of benefit versus cost. The study would be conducted in two phases. Phase 1 would require 3 years to complete and is estimated to cost a total of $9.5 million in U.S. dollars, which is equivalent to $14.25 million in Canadian dollars. This represents the total cost of the Phase 1 study; it is assumed that the cost would be split roughly equally between the two Governments.

The study would be conducted by and these funds allocated to a series of binational teams. The teams would be composed of subject matter specialists serving in their personal and professional capacities from various federal, state and provincial agencies; academia and private consultants; and the stakeholders impacted by Lake Superior regulation. The binational Study Board would conduct overall coordination.

A cost summary, based on the three-year implementation period is presented in Tables 1 and 2. Costs in Canadian dollars were estimated as 1.5 times U.S. dollar costs.

Table 1. Total Cost Summary for Phase 1 (Thousand U.S. dollars)

Study Components	YR1	YR2	YR3	Total
Ecosystem	400	1,300	400	2,100
Recreational Boating and Tourism	250	250	250	750
Hydropower	100	150	150	400
Commercial Navigation	150	150	150	450
Municipal, Industrial, and Domestic Uses	150	200	200	550
Coastal Zone	250	400	350	1,000
Future Basin Land Use Changes	100	100	100	300
Hydrologic and Hydraulic Evaluations	700	400	400	1,500
Evaluation	200	200	200	600
Public Involvement	200	200	200	600
Study Management	400	400	450	1,250
Grand Total	**2,900**	**3,750**	**2,850**	**9,500**

Table 2. Total Cost Summary for Phase 1 (Thousand Canadian dollars)

Study Components	YR1	YR2	YR3	Total
Ecosystem	600	1,950	600	3,150
Recreational Boating and Tourism	375	375	375	1,125
Hydropower	150	225	225	600
Commercial Navigation	225	225	225	675
Municipal, Industrial, and Domestic Uses	225	300	300	825
Coastal Zone	375	600	525	1,500
Future Basin Land Use Changes	150	150	150	450
Hydrologic and Hydraulic Evaluations	1,050	600	600	2,250
Evaluation	300	300	300	900
Public Involvement	300	300	300	900
Study Management	600	600	675	1,875
Grand Total	**4,350**	**5,625**	**4,275**	**14,250**

5.3.2 Phase 2

The costs for Phase 2 are difficult to estimate at this time because the extent of data collection and analysis that may be required would only be known at the completion of

Phase 1. However, a range of costs has been estimated for planning purposes. Tables 3 and 4 outline the estimated range of costs for each individual study area.

Phase 2 costs have been estimated to range from approximately $7 to $10 million in U.S. dollars (about $10 to $15 million Canadian dollar equivalent). Phase 2 is presented as a broad range because the exact nature of the required work in Phase 2 would be unknown until the end of Phase 1.

Table 3. Cost Range for Phase 2 (U.S. Thousand Dollars)

Study Components	**Expected Range ($K, U.S.)**
Ecosystem	700-1,500
Recreational Boating and Tourism	0
Hydropower	200-250
Commercial Navigation	400-600
Municipal, Industrial, and Domestic Uses	100-250
Coastal Zone	2,000-3,500
Future Basin Land Use Changes	0
Hydrologic and Hydraulic Evaluations	900-1,200
Evaluation	600-1,000
Public Involvement	600
Study Management	1,250
Grand Total	**6,750 –10,150**

Table 4. Cost Range for Phase 2 (Canadian Thousand dollars)

Study Components	**Expected Range ($K, Canadian)**
Ecosystem	1,050-2,250
Recreational Boating and Tourism	0
Hydropower	300-375
Commercial Navigation	600-900
Municipal, Industrial, and Domestic Uses	150-375
Coastal Zone	3,000-5,250
Future Basin Land Use Changes	0
Hydrologic and Hydraulic Evaluations	1,350-1,800
Evaluation	900-1,500
Public Involvement	900
Study Management	1,875
Grand Total	**10,125-15,225**

ANNEX 1
STUDY ORGANIZATION

The following governmental agencies and academic institutions could assist the Study Board with the technical resource committees listed below. Private companies, organizations, and individuals that have specialized experience and technical capabilities may be asked to provide technical support to the committees, but would not be an official member of the committees. These organizations are also listed below and identified by an asterisk. Committee membership should be reserved for public agencies and institutions.

Technical Resource Committees

Ecosystem

United States

U.S. Geological Survey
U.S. Environmental Protection Agency
U.S. Army Corps of Engineers, Detroit and Buffalo Districts
Michigan Department of Environmental Quality
Ohio Environmental Protection Agency
Wisconsin Department of Natural Resources
Minnesota Department of Natural Resources
U. S. Fish & Wildlife Service
Michigan State University
University of Minnesota – Duluth and – Minneapolis St Paul
University of Wisconsin
NOAA Sea Grant Program and GLERL
Ohio State University
Indiana Geological Survey
Native American/Tribal Organizations
Lake Management Plan (LaMP) Teams
*The Nature Conservancy

Canada

Environment Canada, Ontario Region
Fisheries and Oceans Canada
Ontario Ministry of Natural Resources
Conservation Authorities
Ontario Ministry of Environment
First Nations

Recreational Boating and Tourism

United States

U.S. Army Corps of Engineers, Detroit and Buffalo Districts
U.S. Coast Guard
Michigan State University
NOAA Sea Grant Program

Canada

Ontario Ministry of Natural Resources
Environment Canada, Ontario Region
Canadian Coast Guard
Canadian Hydrographic Service
*Ontario Marina Operators Association

Hydroelectric Power

United States

U.S. Army Corps of Engineers, Detroit District
*New York Power Authority
*Edison Sault Electric

Canada

Ontario Energy Board
Ontario Ministry of Energy, Science and Technology
*Great Lakes Power Company
*Ontario Power Generation
*Canadian Electricity Association
*Ontario Water Power Association
*Canadian Waterpower Association

Commercial Navigation

United States

U.S. Army Corps of Engineers, Detroit and Buffalo Districts
U.S. Army Corps of Engineers, Institute for Water Resources
U.S. Coast Guard
*Lake Carriers Association
*U.S. Great Lakes Shipping Association
*Western Great Lakes Pilots Association

Canada

Canadian Coast Guard
*Shipping Federation of Canada
*Canadian Ship Owners Association
*FedNav Limited
*Transport Canada
*Canadian Pilotage Authority
*St. Lawrence Seaway Management Corporation

Municipal, Industrial, Domestic Water Uses

United States

N.Y. State Dept. of Health
Public Works/ Municipality Representatives
U. S. Environmental Protection Agency
U.S. Geological Survey
Michigan Department of Environmental Quality

Canada

Ontario Ministry of Environment and Energy
Environment Canada
Environment Canada National Water Research Institute
Public Works/Municipality Representatives
Ontario Ministry of Northern Development and Mines

Coastal Zone

United States

U.S. Army Corps of Engineers, Detroit and Buffalo Districts
U.S. Army Corps of Engineers-Waterways Experiment Station
Michigan Department of Environmental Quality
Wisconsin Department of Natural Resources
NOAA Sea Grant Program
Ohio Department of Natural Resources
Minnesota Department of Natural Resources
U.S. Geological Survey
Indiana Geological Survey

Canada

Environment Canada, Ontario Region
Ontario Ministry of Natural Resources
Conservation Authorities
Ontario Ministry of Municipal Affairs and Housing

Future Basin Land Use Changes

United States

U.S. Army Corps of Engineers, Detroit District
Michigan Department of Natural Resources
Wisconsin Department of Natural Resources
U. S. Forest Service

Canada
Environment Canada, Great Lakes-St. Lawrence Regulation Office

Hydrologic & Hydraulic Modeling

United States
U.S. Army Corps of Engineers, Detroit District
U.S. Army Corps of Engineers -Hydrologic Engineering Center
U.S. Army Corps of Engineers – Great Lakes and Ohio River Division
Great Lakes Environmental Research Lab
U.S. Army Corps of Engineers -Institute for Water Resources, Ft. Belvoir
U.S. Geological Survey
U. S. Forest Service
Indiana Geological Survey

Canada
Environment Canada, Great Lakes-St. Lawrence Regulation Office
Environment Canada, Meteorological Service of Canada-Ontario
Institut National de la Recherche Scientifique – Eau (INRS-EAU)

Public Involvement

United States
U. S. Army Corps of Engineers, Detroit District
International Joint Commission
NOAA Sea Grant Program

Canada
Environment Canada, Ontario Region
International Joint Commission
Fisheries and Oceans Canada
Ontario Ministry of Natural Resources
Conservation Authorities

* - Private company or interest group that could provide technical expertise to committee members.

Evaluation Group

This committee would be composed of one or two representatives from each of the other

committees/teams.

Interest Advisory Group

This committee would be composed of a mix of individuals equitably representing each of the above interest areas. Individuals could be from property associations, private companies, interest groups, or organizations.

ANNEX 2
CONTRIBUTORS

Study Team and Section Leads

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ANNEX 3
DIRECTIVE TO UPPER GREAT LAKES PLAN OF STUDY TEAM

August 13, 2001

The purpose of this directive is to establish and direct the Upper Great Lakes "Plan of Study" Team (Team) to develop a Plan of Study (POS) to review the operation of structures controlling the outflows from Lake Superior. The purpose of the study is to (i) review the operation of the structures controlling the outflows from Lake Superior in the light of the impacts of those operations on water levels, flows, and consequently affected interests in the upper Great Lakes system from Lake Superior downstream through Lake Erie, including the environment; (ii) assess whether changes to the Orders or regulation plan are warranted to meet contemporary and emerging needs, interests and preferences for managing the system in a sustainable manner, including under climate change scenarios; and (iii) evaluate any options identified to improve the operating rules and criteria governing Lake Superior outflow regulation. The POS will be conducted in the context of Articles III and VIII of the Boundary Waters Treaty and the Commission's alerting responsibilities.

This POS shall include:

a. the definition of the studies to be performed and the level of detail anticipated for each study,
b. recommendations as to the agencies or organizations capable of carrying out each study, recognizing that studies are to be conducted binationally,
c. sources of, or means of obtaining, needed information, and
d. recommendations on the order and duration of the study and its phases (in the case of a phased study), and
e. estimates of the time, dollar and personnel resources required for the conduct of each unit of the study.

Consideration shall always be given to the goal of an improved operating plan in formulating the extent to which any topic or issue is to be studied. At a minimum, the following studies or activities will be required:

a. Review of available data and research that will inform and prioritize studies and activities to be completed through the POS
b. System flow and level modeling using compiled historical flow records, available post-glacial levels information, extended supply variability data, and considering current diversions into and out of the Great Lakes system
c. Climate change impacts on levels and flows
d. Effects of past and current dredging on levels and flows
e. Groundwater impacts on levels and flows
f. Defining the amount of anthropogenic regulation effects compared to natural levels and flows in the system
g. Development of alternative control approaches that as nearly as possible meet the needs of all interests (including the integrity of the ecosystem),

appropriately balance effects between Lakes Superior and Michigan-Huron while considering impacts on the St. Marys River and downstream of Lakes Michigan-Huron (including on Lake Erie), make provision for emergency conditions, and respect the requirements of the Boundary Waters Treaty and in particular Article VIII

h. Ongoing public involvement in executing the study, including institutional arrangements to ensure appropriate communication with and among all interests, as well as a means of testing and demonstrating the effects of possible scenarios with the public
i. Development of recommendations concerning appropriate communications on Lake Superior outflow regulation with and among all interests following completion of the study
j. Development and implementation of an evaluation methodology for characterizing and assessing impacts associated with various water level and flow scenarios
k. Impacts of levels and flow regimes on the natural ecosystem, including consideration of the viability of native biological diversity (species, natural communities, and ecological systems)
l. Determination of levels and flows impacts on recreational boating and tourism, riparians, hydropower, commercial navigation, and municipal water supply, in the light of the 1909 Boundary Waters Treaty
m. Shoreline impacts of levels and flows, including assessment of zoning and other land use management issues
n. Qualitative assessment of how demographic and other possible future changes may affect user needs, water supplies, and regulation impacts
o. Topographic and bathymetric data acquisition

Emphasis shall be placed on making the best possible use of available data and promoting coordination with related ongoing efforts, including studies on dredging of connecting channels in the Great Lakes, the Lake Michigan Potential Damages Study, and the Commission's reports and supporting studies on alleviating the adverse consequences of fluctuating water levels and protecting the waters of the Great Lakes.

Consideration shall be given as to whether it is desirable to conduct the study in a phased approach. One possible phased approach is where the first phase would compare the degree of anthropogenic control over Lake Superior outflows in relation to natural variability in flows and resulting water levels, including under climate change, while the second phase would investigate various approaches to Lake Superior outflow regulation.

The Commission shall appoint an equal number of members from Canada and the United States to the Team. Members act in their personal and professional capacities and not as representatives of their countries, agencies, organizations, or other affiliations. Members of the Team shall be responsible for their own expenses unless otherwise arranged by the Commission.

The Team shall consult with others as necessary, and especially the International Lake

Superior Board of Control, to complete its work. It shall take note of work of all other agencies and organizations in both countries in order to make the most effective use of resources and efforts in both countries. It shall consult with the St. Lawrence River Study Board, currently conducting studies for the St. Lawrence River basin, to determine how best to leverage progress from that study applicable to the upper Great Lakes.

The Team shall keep the Commission informed of its progress and direction. The Team shall submit to the Commission:

1. Within two weeks of its formation, a document outlining how it plans to proceed in developing a POS, with special emphasis on public involvement;
2. Within one month of its formation, a document framing the general nature of the anticipated POS;
3. By October 18, 2001, a draft POS; and
4. By January 11, 2002, a final POS (an electronic copy and 500 printed copies provided to each section of the Commission.)

The Team shall make use of public input received prior to and during the development of the POS. The team shall distribute information widely to raise awareness of the effort to develop a Plan of Study and the purpose of the proposed study. To the extent possible, the development of the POS shall be an open and transparent process. The Team shall provide opportunities for the public to comment on the draft POS concurrently with the Commission's review. The Team shall coordinate its public involvement plans with the Commission.

Documents, letters, memoranda, and communications of every kind in the official records of the Commission are privileged and become available for public information only after release by the Commission. The Commission considers all documents in any official files that the team may establish to be similarly privileged. Accordingly, all such documents shall be so identified and maintained as separate files. The Commission will work with the Team to assure that relevant information is available for public review in a timely manner.

To assist in carrying out this assignment, attached are copies of the following:

a. 1909 Boundary Waters Treaty
b. Commission Orders of Approval
c. Commission report, *Methods of Alleviating the Adverse Consequences of Fluctuating Water Levels in the Great Lakes - St. Lawrence River Basin: A Report to the Governments of the Canada and the United States*, December 1993
d. March 19, 1996, Scope of Work, developed by the International Lake Superior Board of Control
e. Membership of the International Lake Superior Board of Control
f. Membership of the International Lake Ontario - St. Lawrence River Study Board

g. September 1999 Plan of Study for Criteria Review in the Orders of Approval for Regulation of Lake Ontario - St. Lawrence River Levels and Flows

h. Comments received by the Commission regarding the draft directive to the Upper Great Lakes Plan of Study Team

i. Commission report, *Protection of the Waters of the Great Lakes: Final Report to the Governments of Canada and the United States*, February 22, 2000

ANNEX 4
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ANNEX 5
SUMMARY OF CONSULTATION

Consultation with members of the public, First Nations/Native Americans, interest groups, shoreline associations, and state and local agencies has been a critical part of the formulation of this Plan of Study. Beginning at the early stages of the project when the IJC was formulating the Directive, consultation was instrumental in shaping the overall plan. The IJC consulted or received comments from the following groups and individuals in the spring and early summer of 2001 prior to forming the POS team:

Great Lakes Commission
U.S. Congressional members of Great Lakes States and staff
Lake Superior Binational Forum
Great Lakes Fishery Commission
Great Lakes Mayors
Great Lakes United
Edison Sault Electric Company
Chippewa Ottawa Resource Authority
International Great Lakes Coalition
WayWahTaysee Association
Ohio Department of Natural Resources
New York State Department of Environmental Conservation
Michigan Department of Environmental Quality
Pennsylvania Department of Environmental Protection
Illinois Division of Water Resources Management
The Nature Conservancy
Minnesota Department of Natural Resources
U.S. Geological Survey
U.S. Department of State
Great Lakes Boating

After the POS team was formed in August 2001, the team consulted with or received comments from the following individuals and groups during preparation of the draft Plan of Study:

International Great Lakes Coalition, Wisconsin
Whitefish Bay Shoreline Association
Georgian Bay Association
Edison Sault Electric Company
U.S. Coast Guard
Great Lakes Shipping
Shipping Federation of Canada
Great Lakes Power Limited
Lake Carriers Association
USS Great Lakes Fleet

Western Great Lakes Pilots Association
Environment North, Thunder Bay
National Marine Conservation Area
Northwest Region Advisory Committee
Union of Ontario Indians (1850 First Nations)

As noted in the POS document itself, the POS team sent a preliminary draft document to over 20 peer reviewers to obtain their comments and input. The peer reviewers were selected as representative of a broad range of interests, expertise, and geography.

Following preparation of the draft POS, the team sent nearly 400 copies of the document to members of government, First Nations/Native Americans, agencies, associations, groups, and members of the public. The draft POS was also made available on the team's website for downloading. To further publicize the study, the POS team held eight public meetings throughout the Upper Lakes Basin to solicit comments on the draft report. Meeting dates and locations were as follows:

October 31: Duluth, Minnesota
November 1: Thunder Bay, Ontario
November 5: Sault Ste. Marie, Ontario
November 6: Muskegon, Michigan
November 7: Milwaukee, Wisconsin
November 13: Parry Sound, Ontario
November 14: St. Clair Shores, Michigan
November 15: Cleveland, Ohio

Aside from team members and associates, there were a total of about 80 other participants at the eight meetings. The vast majority of participants represented some 20 different non-governmental organizations, several of which have memberships numbering in the thousands. The next largest number represented state and provincial government agencies. Broad support was expressed for both the study and the proposed approach.

The POS team received written comments from the following individuals and groups on the draft POS. The team reviewed all comments (including those received at the public meetings) and incorporated comments as appropriate.

Sierra Club
The Nature Conservancy
Georgian Bay Association
Lake Superior Binational Forum
Michigan Department of Natural Resources, Parks and Recreation Bureau
U.S. Army Corps of Engineers, Great Lakes and Ohio River Division, Water Management Team
Ohio Lakefront Group
National Wildlife Federation
Indiana Geological Survey

New York Department of Environmental Conservation
Ojibways of the Pic River First Nation
Michigan Department of Natural Resources, Alpena Great Lakes Fisheries Research Station
U.S. Department of Transportation, Maritime Administration
Michigan Boating Industries Association

All comments received in person and in writing during formulation of the Directive, the draft POS, and the final POS were carefully reviewed and evaluated by the POS team. Not all comments could be directly incorporated. Some were outside the scope of the work and some conflicted directly with the IJC's Directive. The overwhelming majority of comments were very constructive additions or modifications to the text. The team incorporated these into the final POS. The POS team appreciates the careful review and intense level of interest by so many organizations and members of the public.